Fire Safety Evaluation of Ecclesiastical Estate

The Development and Application of a Fire Safety Evaluation Procedure for the Property Protection of Parish Churches

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Abstract

The environment in which we live relentlessly threatens to decay or destroy our built cultural heritage through climatic and man-made means. Fire presents the most severe threat to the fabric and content of historic buildings. The destruction, when it occurs is extremely swift, the loss caused is often complete and the indirect damage from smoke and water can also be significant.

The incidences of fires in churches is currently exceeding those in all other historic building types. This trend is destroying irreplaceable national treasures as arguably, England and Wales contains the greatest collection, in terms of number and antiquity, of ancient parish churches in the world.

This thesis presents an investigation into the fundamental principles underlying fire safety in parish churches. It identifies that the danger to life from fire is not high, due to the fact that the natural layout of churches facilitates good evacuation routes and travel distances. The threat to church property, however, is considerable as churches generally possess very limited fire safety measures. In addition, problems of building isolation, restricted access and limited water supply means that early intervention is unlikely. Such evidence prompted the need for a decision making tool to aid the custodians of churches in the management of fire safety and in the allocation of scarce resources.

The aims of this thesis were to develop a prototype fire safety evaluation procedure for the property protection of parish churches and to examine, using a sample of churches, the effectiveness of the methodology. This has been achieved by developing a 'points scheme' technique to enable the judgement on the adequacy of fire safety to be undertaken. The work involved assigning numerical values to qualitative descriptions of events, techniques and processes by a group of experts representing the interests of those involved in the use, management, and preservation of churches as well as fire safety engineering. The opinions gathered were brought to a consensus in a series of Delphi group meetings, through discussion and matrix manipulation. A 'collated norm' was established, from a collection of fire safety guidance documents for places of worship, against which technical value judgements are made and the acceptable level of fire safety is adjudicated. The procedure is unique in its evaluation configuration, in that it balances the level of fire safety against the vulnerability of property fabric and content.

The assessment is undertaken through an 'observational survey'. This is conducted by an expert, knowledgeable in ecclesiastical building construction and fire safety, observing all parts of the building and making judgements on the adequacy of eighteen identified fire safety components. Features of the building which are highlighted through the assessment as being a high fire risk can receive a more in-depth survey, beyond the scope of this evaluation procedure.

The practical operation of the evaluation procedure has been tested on ten churches. The outcome shows a broad spread of results. An independent qualitative observational assessment by experts support the outcome of the evaluation procedure in nine out of ten cases. Preliminary repeatability application trials have also been conducted. They showed an encouraging level of consistency, illustrating further that the developed procedure is of positive value and utility. The versatility of the evaluation procedure enables a direct link to be made between potential improvements in the assessment score and the actual cost of making fire safety improvements. This facility enables decision makers to evaluate fire safety upgrade options.

Acknowledgements

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Dedication

to 'little Eloise'

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Glossary of Terms

Liturgical terms

Aisles: Subsidiary space alongside the nave

Altar: Elevated slab or board consecrated for the celebration of the Eucharist

Aspe: The curved east end of a chancel

Belfry: The chamber or stage of a tower where bells are hung

Chancel: The east arm of a church

Chantry chapel: Chapel, often attached to or screened off inside a church

Clerestorey: Uppermost storey of the walls of a church, pierced by windows, normally above an arcade

Hatchment: a lozenge-shaped wooden panel, painted with the armorial bearing of a deceased person

Lady chapel: Any chapel with an altar to the Virgin Mary

Lectern: A desk normally used for reading the Scriptures

Lychgate: Roofed gateway at the entrance to a churchyard where a coffin may be rested

Litany desk: Desk at which the rector of the Litany knelt

Mausoleum: Monumental sepulchral chamber usually intended for the members of one family

Nave: The body of a church west of the chancel often flanked by aisles

Pendant: Decorative feature hanging from a ceiling, usually ending in a boss

Pew: An enclosed seat with high sides

Porch: A covered projecting entrance

Pulpit: Raised and enclosed platform used for the preaching of sermons

Reredos: Enriched fixed screen behind and above the altar

Ringing chamber: Stage in the tower where the bell ringers stand

Rood: A cross or crucifix, usually on a beam over the entry into the chancel

Rood screen: A wooden screen sited between the chancel and the nave

Sacristy: Room for storing sacred vessels and vestments

Sanctuary: An area immediately around the main altar

Parclose screen: A screen which separates a chapel from the rest of the church

Sedilia: Seats for the clergy, generally on the south side of the chancel

Sounding board: The horizontal board or canopy over a pulpit

Spire: A tall pyramidal or conical feature built on a tower.

Broach spire: A spire starting from a square base, then carried into an octagonal section by means of inverted triangular faces

Needle spire: Thin spire rising from the centre of a tower roof, inside the parapet

Stall: Fixed seat in the chancel, with projecting arm rests

Choir stall: Fixed seating in the chancel, framed together like a bench

Steeple: Tower together with a spire

Transept: Transverse portion of a cross-shaped church

Triforium: An arcaded wall passage usually forming the middle storey of an internal elevation, its height corresponding to that of the aisle roof

Turret: A small tower, surmounting or attached to a church

Vault: Ceiling of stone, sometimes imitated in timber or plaster

Vestry: Robing room

Vice: A small spiral stair

Vestibule: An entrance hall or lobby

Fire safety terms

Acceptable [typical] contribution: The expected component contribution to fire safety

Building evaluation: An evaluation of the structure, layout, use and management of a building

Building fire performance evaluation: An evaluation of the behaviour of fire in a building and the behaviour of a building subject to fire

Collated norm: An assembled document, which represents the fire safety benchmark against which the assessment of fire safety is made

Expert assessor: One who has an expert knowledge of building technology, a broad appreciation of church architecture and construction methods and an understanding of fire safety issues and principles

Fire assessment: The overall process of estimating the fire risks and fire safety measures within a building and deducing the degree to which the risks are mitigated by the fire safety measures, with the outcome being measured against a benchmark

Fire engineering [or holistic fire safety]: Design which considers the building as a complex system and fire safety as one of the many interrelated subsystems which can be achieved through a variety of equivalent strategies

Fire hazard: A hazard is an object or situation with the potential to do harm

Fire risk: The probability that a particular hazard will cause harm

Fire load: The amount of fuel within a room or building which will burn to release heat and feed the growth of the fire

Fire safety objectives: The specific objectives which must be satisfied in order to achieve a fire-safe building

Fire safety tactics: Fire safety alternatives, each of which contribute to the fulfilment of the fire safety objectives

Fire safety components: The specific building elements, structures and procedures, which are used tactically to achieve fire safety

Fire safety sub-components: Essential elements of the components which can be readily identified

Fire tight enclosure: An area enclosed with fire and smoke resisting walls, floors and doors

Fire attack time: The time taken for the fire brigade to respond to a detected fire and set out their fire fighting facilities

Fuel load: The amount of potential fuel within a building or room; this includes both the building's fabric and the content

Hazard management: The management of hazards, before, during and after a disaster

Immobile fuel load: All combustible material which forms the shell and/or structure of the building

Least-cost upgrade: Optimisation technique to identify the least-cost means of fire safety upgrade

Maximum attainable [score]: The maximum practically attainable fire safety measure score through making improvements to a building

Mobile fuel load: All combustible material which can be removed from the building without affecting the shell of the building and/or the structural members

Non-expert assessor: One who has no professional knowledge of building technology, construction methods, ecclesiastical architecture or fire safety

Perfect contribution: A component making a perfect maximum possible contribution to fire safety

Risk assessment: The process of estimating the danger to life and/or property within a building, by firstly identifying hazards and then estimating the likelihood of harm occurring and a measure of its severity

Safety assessment: It may be used as an alternative term for fire assessment

Semi-expert assessor: One who has a good knowledge of building technology and construction methods, but only a limited knowledge of ecclesiastical architecture and fire safety

Specific perimeter: The measured profile of combustible material

State of division: The natural configuration of combustible material

Stepwise: The process of evaluating fire safety using a time line framework

Time line: A time frame which follows the phenomenological sequence of the development of a fire onto which techniques of intervention may be plotted

Time step: Identified steps along the time line

Other terms

Artifact dissection: The survey breakdown of a property using the elements of materials, components, sub-assemblies and the final assembly

Assembly: The total church building

Committee group: The acquisition of expert knowledge through the open discussion of issues

Condition dependent [work]: Property maintenance undertaken when the condition of the fabric has deteriorated to a certain condition

Condition independent [work]: Property maintenance undertaken at periodic times regardless of the condition of the fabric

Delphi group: A method for the systematic solicitation and collation of informed judgements on a topic

Desk-top [investigation]: Survey data gathered through interviewing key personnel and research from other sources

First cut [survey]: The initial prototype survey

Historic building: A structure and its associated additions and site deemed to have historical, architectural, or cultural significance by a local, regional or national jurisdiction.

Historic church: A church constructed before 1914

Likert-type [scale]: A six point scale from zero to five

Observable space: A continuous open internal space

Observational survey: A knowledge based survey in which the assessment of fire safety systems are assessed superficially

Panel group: The acquisition of expert knowledge through the open discussion of issues [an alternative to a committee group]

Second cut [survey]: A survey developed after a evaluation of the first cut survey

Spatial layout classification: A system of coding which identifies the layout and interface relationships of sub-assemblies in a property

Sub-assemblies: Identified spaces within a church, which as a collection form the assembly

Threat agents: Agents of decay and destruction which continuity threaten to destroy the fabric and/or content of property

Unique occupancy: A specific building type

Wise men [approach]: The acquisition of expert knowledge through an informal gathering of experts

Abbreviations

ADCS	Automatic detection and communication system
APB	Arson Prevention Bureau
EASA	Ecclesiastical Architects' and Surveyors' Association
BE	Building evaluation
BEPE	Building fire performance evaluation
BFPEM	Building Performance Evaluation Method
BWA	Building worth assessment
CCC	Council for the Care of Churches
CMC	Churches Main Committee
DD240	Draft for development 240
EIG	Ecclesiastical Insurance Group
Fire(SEPC)	Fire safety evaluation procedure for the property protection of parish churches
FPA	Fire Protection Association
FSM	Fire safety measure
FSV	Fire safety value
FV	Functional value
FVR	Fire vulnerability rating
HV	Historic value
IAT	Instant action threat
LIV	Loss impact value
LPC	Loss Prevention Council
MOGSA	Mission, objectives, goals, strategy and actions
NFPA	National Fire Prevention Association
OFM	Operational facilities management
OFSR	Overall fire safety rating
PCC	Parochial parish council
PML	Probable maximum loss
PoML	Potential maximum loss
PPG	Planning and policy guidance
QDR	Qualitative design review
SAT	Slow action threat

CHAPTER ONE

INTRODUCTION

1. INTRODUCTION

1.0 Introduction

This introductory chapter presents the background and the justification for the investigation. The aims, objectives and hypothesis of the thesis are detailed, as is the research methodology. Each phase of the research is then outlined. Finally a guide to the layout of the thesis is provided.

1.1 Background to the investigation

This work was started in June 1993. At that time there was much debate amongst fire safety practitioners and conservation specialists regarding the vulnerability of historic buildings to fire, primarily as a repercussion of the Windsor Castle fire which occurred in November 1992 and the subsequent Bailey report[1]. As a practitioner in construction and building management the author was interested in investigating how fire safety was and should be managed in historic buildings.

The authors' previous commercial experience was in construction management, during which the author became involved with both managing fire safety during the period of construction and for co-ordinating the fire certification of all fabric and furnishings on a series of turn-key hotel contracts.

Upon joining the School of the Built Environment in 1993 an opportunity arose to apply this established interest in fire safety management to existing buildings and in particular, historic buildings.

This thesis bridges a number of professional boundaries which exist in the construction industry. Maintenance, facilities and building management, fire engineering and historic building conservation being the principle subject areas. It has required the author to develop further existing knowledge and expertise as well as acquire considerable new knowledge, specifically in the field of fire safety engineering.

1.1.1 Operational facilities management

The context of this thesis is very much centred in the discipline of operational facilities management [OFM]. OFM, seen as a subsection of facilities management, is concerned with the organisation and control of response and programmed property maintenance. Such maintenance may be expressed as 'condition-dependent' or 'condition-independent' work[2] [see glossary for definitions]. Fire safety forms a core cyclical condition-independent activity.

For any property, the practice of OFM involves the effective co-ordination of a network of interacting subsystems, which, to achieve a coherent balanced strategy, are required to be addressed in a holistic way. For historic buildings, specific problems exist beyond that of new buildings, in that the historic and aesthetic implications of the fabric and content must also be taken into consideration. In this thesis the problems and issues of managing fire safety in such environments are explored.

1.1.2 Fire safety engineering

This thesis promulgates a systemic approach to fire safety, in which a holistic philosophy is adopted. Each building studied is considered as a complex system, with fire safety being just one of the many interrelated subsystems. In terms of fire safety, the specific needs of individual buildings are identified and then measures are implemented which satisfy those needs. The philosophy of using a reasoned process of balancing risk and hazards against safety measures underlie this work.

1.2 Justification for the work

A preliminary investigation quickly revealed that the problems and issues of fire safety in historic buildings are very much building type specific and to undertake a research project of sufficient depth required the examination to be limited to one specific historic building type. For the reasons outlined in this section and discussed in detail in chapter three, parish churches were selected as the focus 'unique occupancy' [see glossary for definition] for this research programme.

Arguably, England and Wales contain the greatest collection, in terms of number and antiquity of ancient parish churches in the world. Their age, their history and their appearance, the quality of their workmanship all combine to make the built fabric irreplaceable.

As structures, parish churches perform a diverse range of functions. Primarily, they provide a home for acts of worship, but in addition, parish churches are dynamic buildings, responding to the needs of modern life in a community, often acting as accommodation for other religious and secular activities. For parishioners they are a shrine to their local history while for the nation as a whole they are a record of the country's past. Thus there is the need to preserve and conserve such buildings for their historical, aesthetic and functional value.

1.2.1 Cost of fires in parish churches

A review of past fire incidents in churches provides further justification for the work. Parish churches exist in an environment which continuously threatens to deteriorate or destroy historic fabric. Fire is identified [see chapter two] as being the agent of destruction with the greatest potential to cause total destruction. Parish churches are vulnerable to fire attack, specifically by malicious or deliberate acts of fire raising [see chapter four]. Statistics show that between 1991 and 1995 fires in historic churches accounted for 52% of all fires in historic buildings [with a loss greater than £250,000][3]. Figures[4] from the Ecclesiastical Insurance Group [EIG] show that incidents of fires along with theft and vandalism, which often lead to fires, are currently occurring at the rate of approximately seventeen churches per day and that one in four churches can expect to suffer an incident over a twelve month period. EIG figures state that the cost of reported fire loss between 1990 and 1994 was £26.5 million[5].

1.2.2 Serious fires in parish churches

The gravity of such destruction can only be totally appreciated if one has the misfortune of being associated with a major parish church fire. The reality of the aftermath of a church fire is graphically illustrated in figure 1.1. The image shows the burnt-out ruins of St Peter's, Eaton Square, London following an arson attack in October 1987. Only the walls and tower of the building survived the fire. The church was one of the finest examples of a high Victorian church in the country[6].

The list of serious fires in parish churches continues to grow. A sample of such incidents in England and Wales are shown in table 1.1. Further examples are discussed in chapter three.

Figure 1.1: The consequence of fire: St Peter, Eaton Square, London

Photograph: Arson Prevention Bureau [copyright]

Table 1.1: A sample of serious fires in parish churches

Church	Date	Damage	Cause
St Barnabas Dulwich, London	1992	Interior gutted	Malicious ignition
Holy Trinity, Buckfasleight, Devon	1991	Interior gutted	Malicious ignition
St Mary Pulford, Chester	1991	Wooden spire lost	Lightning
St George Bickley, London	1989	Nave roof lost plus content	Malicious ignition
St Peter Hurst Green, Surrey	1988	90% of the roof lost plus content	Malicious ignition
St Mary-at-Hill London	1988	Belltower and three quarters of the interior	Heat from blow lamp
St Peter Eaton Square, London	1987	Interior gutted	Malicious ignition

Note: Data in this table has been collated from newspaper articles

1.2.3 Protection from fire

Parish churches present a unique and complex environment. As explored in chapter three and four, if a fire becomes established the structure and layout of churches can make them particularly vulnerable to rapid fire spread. In addition, the range of uses to which such buildings are put and their management present a set of circumstances which make the approach to fire safety different from other building types.

Preliminary research identified three principal problems: that of amateur management; the considerable constraints of very limited funds available and the extreme sensitivity required in the installation of active and passive fire precaution measures in parish churches [see chapter three].

Considerable thought was given to the fundamental principles underlying these problems. Discussions with parish church management, diocesan management and fire safety practitioners aided the thought process. Four questions emerged which needed investigation. Why are parish churches more vulnerable to vandalism, theft and fire than other historic building types? Is the existing level of fire safety in churches adequate for the level of vulnerability? Does the building worth of parish churches influence the vulnerability and ultimately the fire safety of the building? How is fire safety in other building types assessed and managed and can ideas be adopted for use in parish churches?

Experience of other building types, such as hospitals[7], shows that the basis of effective fire safety management is a formal strategy, an essential part of which is a structured approach to fire risk and safety evaluation. No procedure exists for parish churches. This thesis details the development and pilot testing of a unique fire safety evaluation procedure for parish churches.

1.3 Aims, Objectives and hypothesis

It is from the context described above that the aims of this thesis were developed.

Aims:

The aims of the thesis are:

- to develop a prototype fire safety evaluation procedure for the property protection of parish churches;
- to examine, using a sample of churches, the effectiveness of the methodology.

Objectives:

To achieve the aims, the following objectives were set:

- to examine the layouts, structures and uses of parish churches;
- to investigate the theoretical behaviour of fire in parish churches;
- to assess the adequacy of existing fire prevention measures and management practices in parish churches;
- to evaluate past fire incident data in places of worship;
- to review approaches to and techniques for assessing fire safety.

Hypothesis:

Further to the outcome of the initial preparatory research, the following hypothesis was postulated:

A formal system for the evaluation of fire safety in parish churches could be a valuable tool, offering simple, repeatable techniques for assessment, an immediate appraisal of acceptability and a method for the rapid identification of deficiencies. This could facilitate the adoption of a suitable, cost effective fire safety strategy.

1.4 Research Methodology and Management

1.4.1 Methodology

The rigour of the methodological approaches to individual investigations are detailed in the text. An overview is provided here. The methodology for this research was divided into three sections. The first section involved a comprehensive literature search in the fields of fire safety engineering and historic building conservation. This produced a resource of secondary data, observed by others and published in books, journals and technical publications.

The second section involved the detailed surveying of ten sample churches and a questionnaire investigation amongst the 310 churches of the Leicester Diocese [the methodology is detailed in chapter six]. This first hand data guided the development of the fire safety evaluation procedure and ultimately enabled the utility of the procedure to be demonstrated.

The third section of the methodology involved the development and prototype testing of the fire safety evaluation procedure. The emphasis of the research programme was to develop a protocol for the procedure. No destructive experiments have been conducted.

1.4.2 Management of the research programme

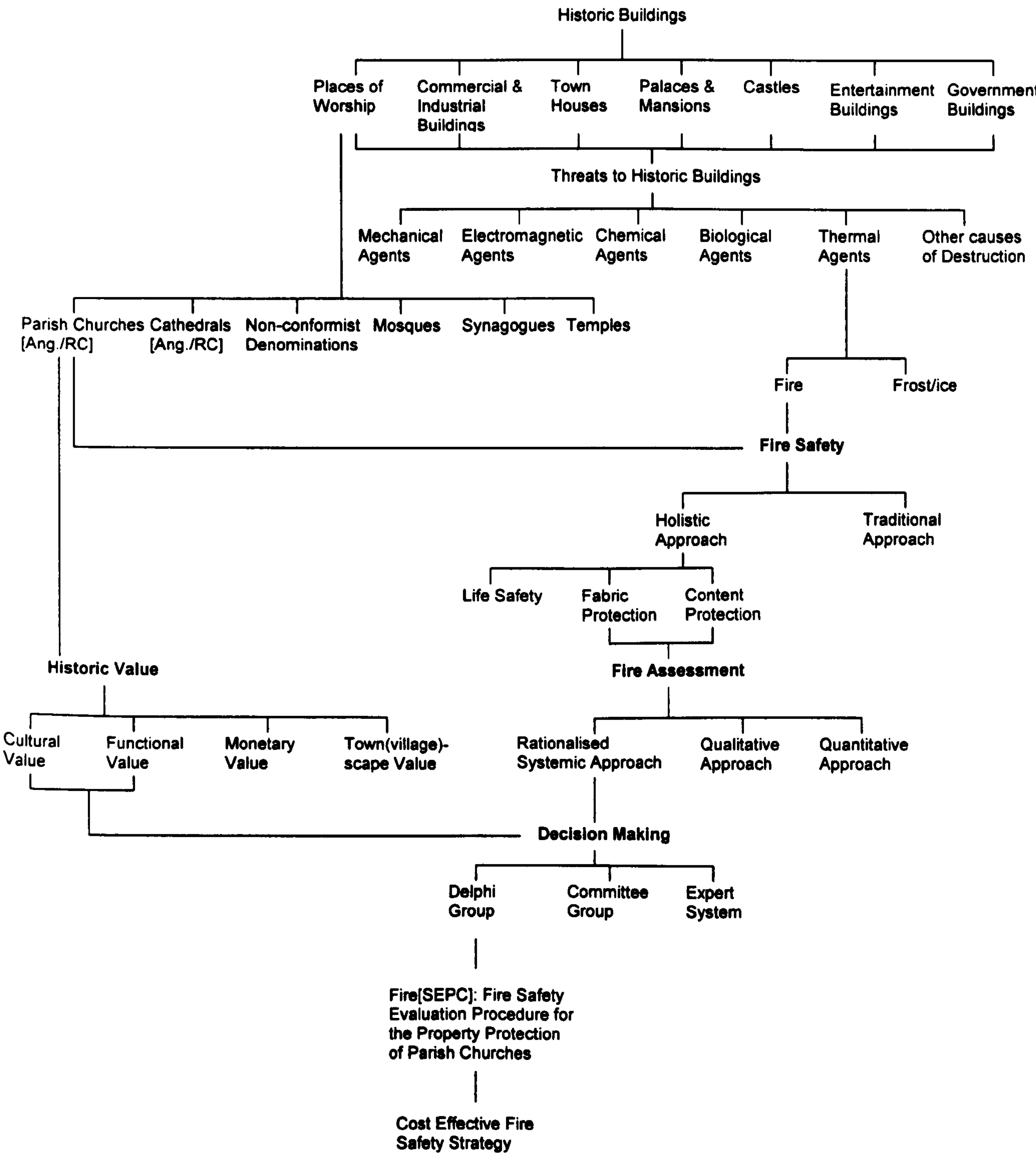
A system of updated summary notes has been used throughout the programme so that the thread of the research could be continued between sessions. In addition, an essential part of the management of this project, has been the storage and retrieval of bibliographic data. During the period of the research a card index system was used for the classification and referencing of text. All references were entered alphabetically under different document types i.e. news item, journal article, government report etc. This gave consistency, flexibility and ease of interrogation.

1.5 Overview of the research work phases

The subject content of the thesis and its development is laid out in figure 1.2. This chart can be used as a guide by the reader to follow the logic of the thesis as it develops.

The research has been undertaken in a series of logical steps. For clarity it is discussed in two sections; the background work and the procedure development and application.

Figure 1.2: Flow diagram showing thesis development



1.5.1 Background work

The background research work has essentially consisted of three phases.

Phase 1: Building evaluation

A clear understanding of parish churches was undertaken in terms of the types of structures and materials used, as well as an insight into the use of the building and the people who use, manage and work in parish churches. This enabled an appreciation of the risk to people, property, firefighters, the environment and the continuity of operation of the building to be gained.

Phase 2: Building fire performance evaluation

This investigation looked at the behaviour of fire in parish churches and the behaviour of parish churches subject to fire. Typical hazards, the origins of fire and possible causes are considered. Fuel loads, fire growth and structural stability were also evaluated.

Phase 3: Selection of an assessment method and technique

The third phase of the background work involved the investigation into methods and techniques of fire safety assessment. Existing procedures were explored and a suitable approach for fire safety evaluation in parish churches devised.

1.5.2 Procedure development and application

Similarly, the second section of the research programme consisted of three phases as briefly detailed below.

Phase 4: Evaluation procedure development

The evaluation procedure was developed on an operational framework in a series of six stepped stages. The stages follow the logical sequence of the evaluation process.

Phase 5: Prior knowledge decision making

A Delphi technique [see glossary for definition] of prior knowledge acquisition was used as a decision making tool in the development of the evaluation procedure. This investigation involved setting up and undertaking a series of structured Delphi sessions. From which process parameter categorisations and weightings were distilled.

Phase 6: Prototype evaluation procedure testing

The final phase of the research programme involved an analysis of the effectiveness of the embryonic evaluation procedure within the limitations of the thesis. A series of pilot tests were undertaken, from which an assessment of the success of the operational sequence of the overall procedure was gauged. Levels of acceptability and an approach to the procedure verification were also suggested.

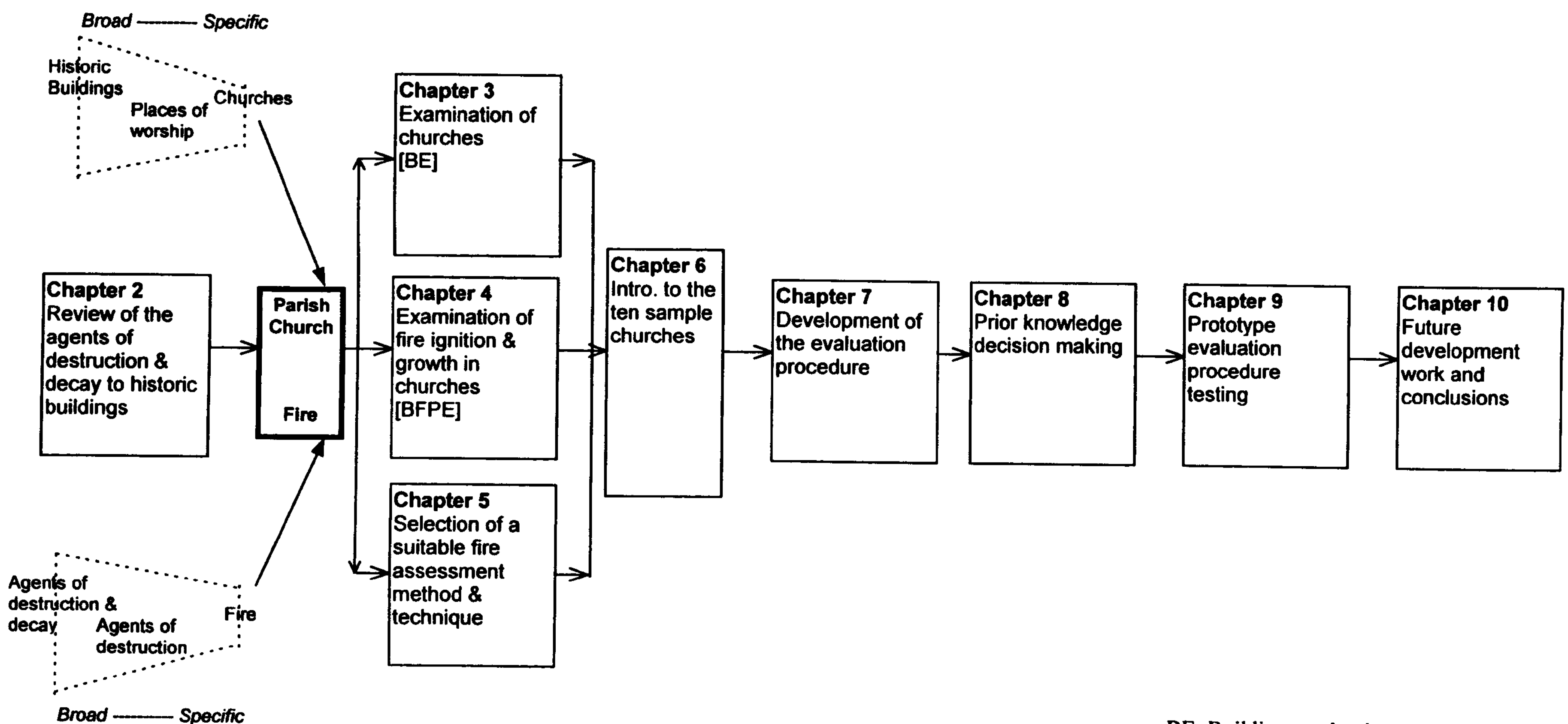
Three studies have specifically influenced the structure of the research. The Building Fire Performance Evaluation Methodology[8] referred to as 'The Method', the British Standard Draft for Development 240: Fire Safety Engineering[9] referred to as DD240 and the Fire Safety Evaluation (Points) Scheme for Patient Areas Within Hospitals[10]. The reasons for these close associations are detailed in chapter five.

1.6 Thesis organisation

This thesis is laid out in the order the research was conducted [as outlined in section 1.5] [see figure 1.3]. Chapter two reviews the range of 'threat agents' [see glossary for definition] present and methods of threat management and property protection are discussed for historic buildings in general. From chapter three onwards the thesis focuses on parish churches specifically. Chapter three undertakes a comprehensive building evaluation, introducing the reader to the structure and function of parish churches. Chapter four undertakes a building performance evaluation which presents clear evidence on the expected performance of parish churches in respect to fire prevention, ignition, fire growth and the application of fire safety precautions. Chapter five explores the methods and techniques of fire safety assessment and chapter six introduces the reader to the survey sample and presents the methodologies and results of other preliminary survey work. [because of the complex integration of many separate elements of research the methodologies are all detailed in chapter six although the results may appear in earlier chapters]. These chapters represent the groundwork of the thesis.

The second half of the thesis starts with chapter seven. This chapter charts the development of the evaluation procedure. The stages of its creation are identified, the problems of its evolution are discussed, as is the method of its intended operation. In chapter eight the Delphi approach to prior knowledge acquisition is introduced, discussed

Figure 1.3: Thesis structure



BE: Building evaluation
BFPE: Building fire performance evaluation

and its application to this problem described. Chapter nine analyses the effectiveness of the prototype evaluation procedure within the limitations of the thesis through a series of pilot tests. Verification, levels of acceptability and strategy development are also covered. Chapter ten forms the synopsis of the thesis, summarising what has been achieved, projects as to the problems and issues which lie ahead and draws conclusions on the contribution of the thesis to the development of fire safety evaluation procedures.

It is hoped the lay out of the thesis enables the reader to ease into the subject area. Sufficient information is presented for the reader to build up the necessary knowledge and background information to become fully cognisant with all the factors that make-up the development of the evaluation procedure. A moderate knowledge of construction technology, fire safety and the workings of The Church of England is assumed, however, due to the restriction on the size of the thesis. The reader is directed to the glossary for necessary definitions of specific fire and liturgical terms. In addition, the reader is warned to check the definition of all terminology used, as some words used may be interpreted differently by some practitioners.

References are made in the text to published material written by the author. These articles focus in detail on different aspects of the research area conducted at the MPhil stage of the research programme and provide a more in-depth overview of the early preliminary research. The articles are presented in volume two.

It is intended that the thesis is a concise yet informative document. It is believed it is of general interest to those with practical or theoretical experience of fire safety assessment techniques. And of constructive use to both, academics wishing to develop the method of assessment further and to practitioners and those responsible for church management wishing to apply the developed prototype fire evaluation procedure.

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CHAPTER TWO

HISTORIC BUILDINGS: AGENTS OF DESTRUCTION AND DECAY

2. HISTORIC BUILDINGS: AGENTS OF DESTRUCTION AND DECAY

2.0 Introduction

This chapter sets the research project in its context. It provides an introduction to historic buildings and presents justification for the need to preserve such buildings. The threats of historic fabric and content attack by agents of destruction and decay are then reviewed and methods of threat management and property protection are discussed. Finally, an overview is given of the particular issues which make historic buildings vulnerable to fire.

2.1 Historic Buildings

2.1.1 Their range, function and use

An historic building may be concisely defined as 'a structure and its associated additions and site deemed to have historical, architectural, or cultural significance by a local, regional, or national jurisdiction'[1]. Fielden[2] sees historic buildings as being ones that gives us a sense of wonder and makes us want to know more about the people and culture that produced them.

In the United Kingdom buildings are deemed historic by being listed or scheduled as an ancient monument. The basis of the statutory listing system for England and Wales is detailed in S1 of the Planning (Listed Buildings and Conservation Areas) Act 1990. The number of listed buildings in England in 1993 was 500,000, some 6% of the country's building stock[3]. Table 2.1 shows the classification of list entries. [the criteria for list grading assessment is shown in appendix A1]

Buildings are scheduled as ancient monuments under the Ancient Monuments and Archaeological Areas Act 1979 [applicable to England and Wales]. There are about 13,000 ancient monuments which are defined as 'any building, structure or work above or below ground level and any excavation or cave'[4]. Some buildings may be both scheduled and listed in which case the scheduled monument legislation takes precedence.

Table 2.1: List entries[5]

Grade	Percentage	Description
Grade I	2%	Buildings of exceptional interest
Grade II*	4%	Particularly important buildings
Grade II	94%	Buildings of special interest

In addition, buildings which are nether listed or scheduled may be recognised as having historic interest under the conservation area designation. S69 of the Planning (Listed Buildings and Conservation Areas) Act 1990 [applicable to England and Wales] imposes a duty on local planning authorities to designate as conservation areas any 'areas of special architectural or historic interest the character or appearance of which it is desirable to preserve or enhance'[6]. The designation is very much based on the concept of 'townscape'. There are about 8,000 conservation areas in England.

The nature of historic buildings varies widely, ranging from preserved Scottish crofts, through to defensive castles, ancient town centres, cathedrals, country houses and palaces. Allwinckle[7] presents a list of suggested building types as shown in table 2.2. This list provides a useful categorisation in terms of the buildings use. Although the uses are diverse they all share the common element that they preserve in themselves, elements of our past.

Unlike most other forms of cultural heritage, historic buildings have generally to be capable of paying their way if they are to survive. Caroe[8] divided ancient buildings into three classes based on utility, into which each surviving historic building can be placed:

- Historic buildings which have continued in the use for which they were erected up to the present, and which it is desired to preserve for the same use. Examples being, cathedrals and churches chiefly, detached monuments and may be some schools and mansions.
- Historic buildings which have gone out of use, but which have or are to be recovered to their old use or adapted to a new one, or incorporated into the midst of new buildings.
- Ruins of historic buildings which it is desired to preserve as ruins, and prevent from further decay.

Table 2.2: Historic building types

Historic 'building types'	Historic 'building types' cont.
1. Medieval town houses	13. Local authority buildings
2. Castles	administrative/offices
3. Palaces	libraries
4. Mansions	schools
5. Town Houses	14. Education
6. Terraces	universities/colleges
7. Tenements	15. Health care
8. Suburban villas	hospital buildings
9. Churches	16. Entertainment buildings
medieval	theatres
post reformation	concert halls
10. Cathedrals	cinemas
11. Commercial buildings	17. Sport buildings
offices	18. Agricultural buildings
banks	farm buildings
shops	mills
public houses	19. Industrial buildings
12. Government buildings	manufacturing
administrative/offices	storage
repositories/records	20. Other public buildings
prisons	museums
courthouses	stations
military	harbours/lighthouses
museums	

It is generally accepted that in order to preserve historic buildings in their purest state, continuous original use is best. If that is not possible, and it is so sensitive that it cannot sustain any alterations to keep it in viable economic use, its future may be secured by charitable or community ownership's, preserved for its own sake for local people and visiting public. The National Trust is the largest such charitable organisation in England and Wales. It owns over 200 historic houses, 230 gardens and 25 industrial monuments[9].

But for many historic building their futures are not secure. More than two listed buildings per week are being demolished with consent because they are incapable of reasonable beneficial use[10]. Many old public sector buildings such as naval docks, barracks, old town halls, libraries, government offices and hospitals which have been abandoned through a combination of privatisation, social and technical change are now seeking modern usage in order to survive[11]. It remains a very delicate process for local planning authorities to make the sensitive judgement of balancing the economic viability of possible uses against the effect of any changes they entail on the special architectural and historic interest of the building or area in question[12].

A simple reasoned argument may be presented for the acceptable loss of historic buildings based on the grounds of economic and commercial advantage. Naively, it can be questioned why should we strive to preserve historic buildings, if a new building is deemed to be more effective in terms of aesthetic and functional requirements?

2.1.2 The need to preserve historic buildings

The question as to why should we preserve historic buildings rouses much debate between conservationists and deconstructivists, the arguments of which, are often based less on ideological than emotional grounds. These issues are not debated at length in the thesis but the author agrees with the view of Professor Geoffrey Barrow[13]. In his key note speech to the Scottish Civic Trust's Annual Conference (1995) he identified a deep philosophical divide between those who wish to respect the continuum of social history, who feel that our cohesion depends on an awareness of the links with our own and others' past and on the opposite side, those who feel that improvement, betterment and progress must involve jettisoning any unnecessary historic buildings. He concluded that although a great deal of thoughtless and needless destruction still occurs, the weight of public opinion is probably in favour of conservation.

There are sustained reasons why historic buildings should be preserved. Perhaps, the principal reason for preserving historic buildings is for educational reasons. A major purpose of any historic preservation is to communicate the lessons of history, in order that present and future generations may learn from the past. Historic buildings provide valuable information about how our ancestors lived and worked. By retaining good examples from earlier periods, the better we are placed to judge our contemporary values and our progress. The values of the past provide foundation and reinforcement for the values of today[14]. Although it is not realistic to preserve every old building, it is important to preserve examples of all types [as detailed in table 2.2]. This includes the ordinary homes and community buildings and not just the larger grand buildings of the wealthy and famous.

The historical association of an ancient building is an important cultural element of a community and in some cases a nation. The memory of a nation is based on its technical and cultural creations of the past. If historic buildings are lost, a gap in the historic continuity of the nation is created and as a consequence, they often seek substitutes for their losses[15]. An example being Poland, a country which was extensively destroyed after the Second World War, decided to rebuild its towns and monuments in facsimile.

Historic buildings also have extensive aesthetic qualities. Within a village or townspace they often provide stability and continuity and add to the character of communities. They can be examples of inspiring architecture or exhibit fine craftsmanship.

And, contrary to the consideration presented in section 2.1.1 historic buildings can have considerable commercial value, in terms of viable economic use, tourism and an array of intrinsic values beyond that of modern buildings. [intrinsic value is discussed in section 2.1.3]

Clearly, there is a strong, argument for preserving historic buildings. During the last decade, many governments and international organisations have shown a greater interest in the restoration and conservation of cultural heritage. One example being, the Council of Europe and the European Communities, who have recognised that the continued preservation of historic buildings is of the utmost importance to the enhancement of our European heritage[16].

2.1.3 The value of historic fabric and content

An important element in the historic preservation equation, is the establishment and appreciation of the value of historic properties. A straight forward monetary evaluation of historic sites can be readily established, but beyond the direct use value to their owners, historic buildings have considerable indirect value in terms of their character, quality and beauty which can enhance the value of the property and the immediate area in which the building is set.

These indirect benefits, termed 'externalities' by economists, are usually considered unimportant by the property market, but for historic buildings they form an important element of an historic property's evaluation.

Fielden[17] defines indirect value as intrinsic values and suggests that an assessment of intrinsic value can be divided into three sections; emotional, cultural and use. As shown in table 2.3, further sub-divisions are detailed, covering the cultural and historic significance of the property, as well as the beauty and quality of the architecture and craftsmanship and also the building's function to which the building is used.

Table 2.3: The intrinsic value of historic fabric and content

Emotional values	Cultural values	Use values
Wonder	Documentary	Functional
Identity	Historic	Economic
Continuity	Archaeological	Social
Spirituality & symbolism	Aesthetic and symbolic	Political
	Architectural	Ethnic
	Townscape & landscape	
	Scientific & technological	

Establishing a robust framework for determining the intrinsic value of historic property is a complex undertaking as the valuation of many variables is subjective and influenced directly by the value judgements made by individuals. English Heritage have since 1990 been involved in commissioning a number of studies into the evaluation of intrinsic economic and social values in preserving historic buildings. Recent research studies has been undertaken by Lichfield[18] and Nijkamps[19] into attempting to devise a systematic approach to gauge the social value of conservation.

A consideration of the quantification of intrinsic value is beyond the scope of this thesis, but a suggested approach to an assessment of indirect value is discussed in section 3.4.2.

It is important here to differentiate between the valuation of modern and historic properties. Apart from the intrinsic values historic properties possess, to the extreme of being priceless, there are distinct differences in economic terms to the loss of modern and historic properties as illustrated below.

In terms of the benefits derived from the loss of fabric and content, the loss of a modern building could result in the replacement with present day building and equipment which could be advantageous to business. The fabric and content of historic buildings, however, may represent the business. Or the business could not be run as effectively in a modern building, so any loss is not likely to be beneficial[20]. Exceptions to this theory, however, were demonstrated in fires at York Minster and Windsor Castle where the loss of historic fabric in fact increased revenue. Admission numbers to both buildings increased due to the added increase in interest of viewing, firstly, the damage and then the on-going restoration programmes.

It has been shown that historic fabric and content have values beyond their direct monetary sale value. If such property is to be kept for future generations to admire, how should historic buildings, often containing priceless, irreplaceable fabric and content be preserved?

2.2 Preservation of historic buildings

2.2.1 Approaches to historic building conservation

As has been previously emphasised, historic buildings are a national resource that the country needs now and in the future. To maintain the resource, custodians of these properties need to ensure the preservation of the fabric and contents of such buildings. Unfortunately, this cannot be achieved without some degree of intervention. We live in an environment which relentlessly threatens to decay and destroy such fabric through climatic and man-made means. In addition, there is the requirement to change or improve the way in which buildings function, to enable the survival of a building through modern usage. Any intervention requires a conservation approach.

The underlying objective of building conservation is social, in that looking after the nation's stock of historic buildings and fine architecture is perceived to be in the long term interest of society[21].

The theory and principles of conservation have and continue to evolve. The conservation movement started in the 19th century with the writings of Sir George Scott and John Ruskin especially in the latter works entitled *The Seven Lamps of Architecture* and *The Lamp of Memory*. He considered that 'we have no right whatever to touch them, they are not ours, they belong partly to those who built them and partly to all generations of mankind who are to follow us'[22].

The development of the conservation movement has a number of key dates: These include the manifesto written by William Morris for the Society for the Protection of Ancient Buildings in 1877; the International Restoration Charter or 'Charter of Venice' published in 1966 and the Burra Charter, published in 1981. In addition, the meeting of the 21 member states of the European Union in 1985 produced the signing of the Convention of European Architectural Heritage Protection and the creation of a framework of common policy for the conservation and the distinction of European Architectural Heritage.

Conservation, as defined in the internationally accepted Burra Charter, means 'all the processes of looking after a place so as to retain its cultural significance', which itself is defined as 'the aesthetic, historic, scientific or social value for past, present and future generations'. This neat, constrained definition of conservation is extended by Maguire[23] to reflect the modern rigour of conservation in an economic setting. He offers two definitions:

1. Conservation means retaining and where necessary, adapting or adding to old environments, in such a way that a fresh entity is created to serve modern life, in which the old is respected and valued for its contribution.
2. Conservation means retaining old environments and creating conditions in which they may survive into the future (but essentially unchanged) and users must accept the limitations on their way of life such restriction of change imposes.

In the first definition there is the acknowledgement that historic buildings may have to be altered or added to if they are to survive. Alternatively, in the second definition, if historic buildings are left unchanged then their uses may be severely limited.

The framework for conservation philosophy today is styled on the seven ascending degrees of intervention [see table 2.4]. Minimum intervention, in the form of prevention through routine maintenance and sensitively selected measures should always be the first approach. The actions should be reversible and not prejudice possible future interventions. Preservation is also necessary to some extent in keeping the structure in its existing state. Intervention (approaches three to seven) involves some degree of alteration or addition to the historic fabric.

The minimum intervention approach to conservation is pursued by the major custodians of historic property. The conservation policy of the Historic Royal Palaces Agency are those advanced by the International Council on Monuments and Sites, embracing the concepts of minimum intervention with historic fabric and reversibility of new works

Table 2.4: The seven ascending degrees of intervention[24]

Intervention	Description
1. Prevention	Control of the environment thus preventing agents of decay becoming active. This should include the control of internal humidity, temperature and light, measures to prevent fire, arson, theft and vandalism, as well as sound maintenance and housekeeping procedures
2. Preservation	The objective is to keep the property in its existing state. Repairs must be carried out when necessary to prevent further decay
3. Consolidation	The physical addition of adhesives or supportive materials into the actual fabric of cultural property, in order to ensure its continued durability or structural integrity
4. Restoration	The objective is to revive the original concept or legibility of the object or property. This is based on respect for original material, archaeological evidence, original design and authentic documents
5. Rehabilitation	The practice of adapting the use of the building to enable it to have a use and thus save the property from ruin
6. Reproduction	It entails copying an artefact, often in order to replace some missing or decayed parts
7. Reconstruction	Reconstruction using new materials may be necessitated by disasters such as fire earthquake or war

whenever possible[25]. The National Trust's approach is to ensure the permanent preservation of historic buildings with the minimum of intervention[26].

This thesis is concerned with the protection of historic buildings from agents of decay and destruction. So, it is the first degree of intervention, prevention, that forms the context of this study. An initial consideration of the range of agents that threaten historic buildings is presented.

2.3 Threats to historic buildings

Historic buildings throughout their existence, experience the threat of fabric and content destruction. This threat can be categorised into two types:

1. The threat of complete destruction on the grounds of the replacement of old buildings by new ones. This can be considered a reasonable and natural historic evolution[27]. Buildings can be at risk for a number of reasons, but principally it occurs if the property is allowed to fall into disrepair. The issues of preventing historic buildings becoming at risk are discussed by Cunnington[28] and do not form part of this thesis.
2. The threat of attack by agents of destruction and decay. The range of threats are discussed below.

2.3.1 Overview of threats

The fabric and content of historic buildings, like that of modern buildings are threatened by an array of destruction and decay agents, collectively termed 'threat agents', as detailed in table 2.5.

Table 2.5: Agents of destruction and decay[29]

Nature	Class
Mechanical agents	Gravitation - snow load, rainwater loads Forces - ice formation, expansion and contraction, land slip, creep, flood Kinetic energy - impact, sand storm, wind & hail Vibration and noises - tunnelling, traffic vibration
Electromagnetic agents	Radiation - solar /UV, radioactive radiation Electricity - electrolytic reactions, lightning Magnetism - magnetic fields
Thermal agents	Extreme levels or fast alteration of temperature - frost, thermal shock, heat, fire
Chemical agents	Water and solvents - air humidity, ground water, alcohol Oxidising agents - oxygen, disinfectant, bleach Reducing agents - sulphides, ammonia, agents of combustion Acids - carbonic acid, bird droppings, vinegar Bases - lime, hydroxides, cement Salts - nitrates, phosphates, chlorides, plaster Chemically neutral - limestone, fat, oil, ink
Biological agents	Vegetable and microbial - bacteria, phosphates, chlorides, plaster
Plus:	
Other agents of destruction	Collision - road vehicle, aeroplane Vandalism - malicious damage Theft - resulting in malicious damage and fire

Mechanical agents are those that impose a physical force on the building. This may be a static and permanent load such as ground pressure, flooding and snow load, or static and temporary load such as vibration and inclement weather storms.

Electromagnetic agents occur in the form of radiation, electricity or magnetism. Photochemical effects can cause loss of the colour of the organic materials, while thermal movements can cause the degradation of materials such as plastics. Lightning is the most common type of electromagnetic attack. It can cause collapse or fire to occur.

Thermal agents are those generated by a sudden change in temperature. A drop in temperature can cause harm through frost and ice damage, while a rise in temperature can create fire and the resulting damage from heat, smoke and water used in fire fighting.

Biological agents may be attack by rodents, insects, fungi, algae and plants. Rodents and insects may cause considerable damage to timber and other organic material. Fungi, in the presence of sufficient moisture can attach itself to surfaces which supply nutrients. Algae growth as well as plant life in the form of ivy, moss and lichen can cause deterioration of the material surface and the jointing materials.

The list of potential chemical agents of decay and destruction is extensive. Atmospheric gases such as sulphur dioxide and carbon dioxide can attack certain materials, soluble salts may be present in building materials and may react to cause crystallisation. But it is moisture that must be considered to be the principal chemical agent of decay. In many cases moisture is the prerequisite for mechanical, thermal and biological reactions to take place as identified by Son et al[30].

- Changes in relative humidity can lead to dimensional changes in materials, with deformation, crazing or cracking.
- Rain, when driven by strong winds, can erode and dissolve certain soft materials.
- Water rising from damp ground into walls by capillary action can cause flaking and cracking of wall decorations.
- When water freezes in the pores of materials such as bricks, stones and concrete, stresses are produced which may cause spalling of the surface.
- Presence of moisture can promote corrosion of metals, efflorescence and other chemical reactions.
- Moisture also creates an environment for fungal growth as well as attack by insects in organic materials.
- Giant hailstones can cause damage to glass surfaces and roofing tiles.

There are a number of other agents of destruction which do not fit into the other five sections. Fabric and content destruction can be caused in the act of theft, and vandalism. Destruction can also be caused by collision of a road vehicle, train or aeroplane. In addition, destruction during civil unrest or acts of war can occur.

2.3.2 Potential consequence of threats

Section 2.3.1 has provided a broad overview of all the possible 'threat agents' that have the potential to cause harm to the fabric and content of historic buildings. What is immediately apparent is that the nature of the individual 'threat agents' are considerably diverse in terms of their causes, reactions on the fabric and content and in the potential severity of the reactions. The diversity of the potential severity of harm is illustrated in table 2.6. [severity of harm is defined and further discussed in chapter five]

Table 2.6: Agents of destruction and decay acting on historic buildings

Agent	Cat.	A	B	C	D	Potential damage to fabric & content
Mechanical agents						
Snow/rain water load	IAT	*				B
Flood	IAT			*		C
Wind and hail [storm]	IAT	*				C
Earthquake	IAT			*		A
Subsidence/ground pressure	SAT			*		B
Electromagnetic agents						
Lightning	IAT	*				B
Solar radiation	SAT	*				C
Thermal agents						
Frost/ice	IAT	*				B
Fire	IAT	*	*	*	*	A
Chemical agents						
Air humidity/condensation	SAT	*				C
Carbon monoxide	SAT	*	*			C
Bird droppings	SAT				*	C
Dust	SAT	*	*			C
Biological agents						
Moulds/fungi	SAT	*			*	B
Insects/birds	SAT	*			*	C
Other causes of destruction						
Collision [vehicle/plane/train]	IAT		*	*		A
Vandalism [civil unrest/war]	IAT		*			B
Theft	IAT		*			A

Notes: Categories: IAT = instant action threat, SAT = slow action threat
Causes of destructive action: A = climatic, B = man-made, C = natural, D = biological
Potential damage: A = total destruction, B = partial destruction, C = minor destruction

This table illustrates three integrating factors. Firstly, each agent is categorised as either an agent of decay [slow action threat] or an agent of destruction [instant action threat]. And secondly, the deterioration of fabric is identified as being caused by four distinct aspects:

- Climatic influence: harm caused by internal and external climatic conditions.
- Made-man action: harm caused by the actions of humans.

- Natural disaster: harm caused by events beyond the control of humans.
- Biological involvement: harm caused by the actions of living matter other than humans.

Further to this an estimation of the potential damage from the consequence of each agent is made, in terms of total destruction, partial destruction or minor destruction.

From the list of eighteen agents, eight are identified as agents of decay and the other ten agents of destruction. In general, it is considered that the slow action threats cause less severe damage to property, principally because they emit enough of a warning to treat the problem before the threat occurs. They result in the normal and often prolonged degradation of cultural property.

From the four identified causes of destruction and decay, it is considered that, climate influence, made-man action and biological involvement can be managed. Natural disaster remains largely, an unmanageable cause and so it is those destructive agents caused by natural disasters, coupled with the potential to cause total property destruction that present the most serious threat to historic fabric and content. Earthquakes and fire are the only two agents that qualify for this distinction. In addition, fire can be a reactive consequence of a number of the listed threats including lightning, collision, vandalism, theft and earthquakes.

The potential severity of harm has been explored but to provide a complete analysis of the overall risk, the likelihood or probability [definition and further discussion presented in chapter five] of the agents occurring must be integrated. As a simple indicator the results of a study focusing on historic churches [defintion in chapter three] is presented.

Delphi group participants [detailed in chapter eight] were asked to estimate, using their own judgement, the probability and potential consequence of the above identified destructive agents acting on an historic church. Using a simple risk analysis matrix,[31] [see appendix A2] the following results were derived.

Table 2.7: Risk assessment of the agents of destruction and decay acting on an historic church located in a rural setting

Agent	Probability	Potential consequence	Risk	Risk category
Mechanical agents				
Snow/rain water load	2.9	2.3	6.67	M
Flood	1.6	3.1	4.96	M
Wind and hail [storm]	3	2.1	6.30	M
Earthquake	1	3.4	3.40	M
Subsidence/ground pressure	1.9	3.0	5.70	M
Electromagnetic agents				
Lightning	2.3	2.3	5.29	M
Solar radiation	2.9	1.6	4.64	M
Thermal agents				
Frost/ice	2.9	1.6	4.64	M
Fire	2.1	3.9	8.19	M
Chemical agents				
Air humidity/condensation	3.3	1.9	6.27	M
Carbon monoxide	2	1.1	2.20	L
Bird droppings	2.9	1.3	3.77	M
Dust	2.9	1.0	2.90	L
Biological agents				
Moulds/fungi	2.7	2.7	7.29	M
Insects/birds	3.3	2.0	6.60	M
Other agents of destruction				
Collision [vehicle/plane/train]	1.6	2.9	4.64	M
Vandalism	3.4	2.7	9.18	M
Theft	3.3	2.3	7.59	M

Notes: Average score of seven Delphi participants used

From the example above, it can be seen that when the probability of occurrence is taken into consideration that earthquakes, in the UK, are considered a low-medium risk, as opposed to fire which scores a mid-medium risk.

Of all the 'threat agents' vandalism receives the highest risk rating. This is followed by fire and then theft. If, as illustrated in table 2.6, both vandalism and theft are considered to be generated by man-made causes only, then subsequently with good management the risks can be lowered. The overall risk of fire cannot be dealt with in the same manner.

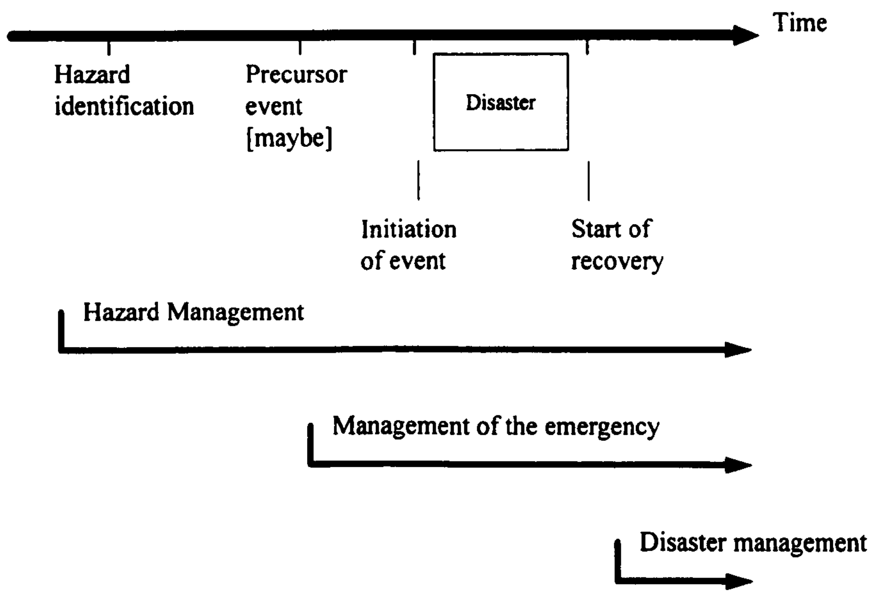
This evaluation, although rather simplistic, serves to illustrate how the 'threat agent' of fire, when considering the potential severity and likelihood of occurrence, exhibits a greater threat to historic fabric and content than any other 'threat agent'.

2.3.3 The management of the threats

It has been established that 'threat agents' can be divided into two types, agents of decay and agents of destruction. For those agents of decay their threat can be reduced by implementing a framework of systematic care. This should consist of a programme of routine maintenance and housekeeping. Such a programme can be based on a quinquennial cycle with routine daily, weekly, monthly, quarterly and annual inspections as suggested by Fielden[32]. Such maintenance will enable potential problems to be spotted at an early stage and will avoid the need for major intervention later.

The management of agents of destruction also requires the completion of a comprehensive maintenance and housekeeping programme. But, in addition, safety management systems must be in place to cope with the actual event of a destructive act occurring. The steps in the sequence leading up to, during and after the occurrence of a destructive act to an historic building are illustrated in figure 2.1.

Figure 2.1: Components of hazard management[33]



The overall process is termed 'hazard management', which consists of two subsections, management of emergencies and disaster management as time specific sub-tasks. A hazard does not always give rise to an emergency while hazard management is always on-going. A test of the success of hazard management is in reducing the probability of emergency and disaster management occurring [this is further discussed in chapter five]. This in turn can be attributed to the selection of the appropriate intervention strategy.

Figure 2.1 also illustrates the time steps from the identification of hazards to the start of recovery after a disaster. In the context of the 'threat agents', each has identifiable or recognisable hazards which present a potential threat. For example, a stack of combustible material is a fire hazard, or a near-by river which floods often is a recognised flood hazard. Effective hazard management will result in the reduction of the threat from the hazard. This can be approached in a number of ways as identified in table 2.8.

Table 2.8: Approaches to threat reduction of destructive agents[34]

Threat reduction	Examples
Avoid threat	Change the use/process in the building
Reduce threat	Reduce quantity of combustible material. Build flood embankments
Threat transfer	Arrange for others to accept potential loss. Insure against threat activation
Hazard protection	Increase quantity and type of protection measures

There will always be some possibility of threats occurring. The question is how great a threat can be accepted given the available strategies for reducing the threat [this question is addressed in the latter stages of the thesis].

2.4 Protection of historic buildings

The protection of historic buildings forms an essential element of any threat reduction strategy, the aspects of which are summarised below.

2.4.1 Protection through legislation

A raft of Parliamentary Acts and Statutory Instruments exist which protect historic buildings from neglect, demolition and control alterations and changes. Crown buildings and ecclesiastical buildings are exempt from some of the legislation. In addition, there exists an extensive array of circulars and planning guidance notes which provide guidance on effective conservation. Perhaps the most influential being *PPG 15: Planning and the Historic Environment*[35], *and BS7913: Guide to the Principles of the Conservation of Historic Building*[36].

With respect to the protection of historic property from destructive agents, various pieces of legislation require measures associated with life safety which do also act as a protector of fabric and content. The Fire Precautions Act 1971[37] and The Health and

Safety at Work Act 1974[38] are two such acts, to which the exact requirements depend on the spatial geometry and the use of the building.

2.4.2 The role of insurance organisations

While life safety is covered by the requirements of legislation, the process of insurance plays a significant role in protecting historic fabric and content. Standard insurance covers the perils of fire, lightning, explosion, storm, escape of water or oil from tanks, theft, riot and malicious damage, impact by aircraft, vehicle, animals, falling trees and flood.

Historic buildings can be insured either on a first loss or a total reinstatement basis. The former covers the largest single risk, short of total loss, and provides for the replacement of lost fabric incorporating modern materials and techniques. Total reinstatement should provide enough money to rebuild completely to the same design, quality, style and in the same materials. However, there have been recent incidents where the costs of reconstruction have been underestimated and owners have found themselves in the situation of not having enough resources to complete the rebuilding[39]. This being primarily due to the underestimation of the cost of using traditional materials, the time for searching and locating such materials and the resourcing of skilled craftspeople.

Insurance organisations are increasingly playing an educational and training role. Advice and information is provided to property owners on 'hazard management' and the steps to be taken to reduce risks. This is further promoted by the incentive of premium reductions if certain physical measures are installed. For example the Ecclesiastical Insurance Group [EIG] offer the following reductions:

Table 2.9: Reductions in insurance premium offered by the EIG

Measure	Reduction
Installation of a detection, alarm and communication system	7.5%
Installation of a security alarm system	7.5%
Protection of windows	2.5%

2.4.3 Protection through physical measures

Physical precautions are utilities to prevent and limit damage to those defined agents of destruction to which buildings could be exposed to in the UK, namely, fire, flood, storm, lightning, collision, vandalism and theft. The range of physical measures deployed is extensive, and as technological advances are made the scope of choice grows and the degree of sophistication of the measures increases. The essential aspect of selecting the measure to be used is the need to consider the sensitive nature of the fabric to which it is to be installed as historic fabric can be destroyed by inappropriate physical precautions as readily as from the destructive agent itself.

A sample of typical measures includes, for security; security alarm systems, security lighting, closed circuit television, access control systems, security fences plus the use of five lever mortice locks, window and door screens and anti-climb paint. Typical fire measures include the use of portable fire extinguishers, hose reels, sprinkler systems, other automatic protection systems, emergency lighting, and fire detection and alarm systems.

So in summary, historic fabric and content is protected from negligent loss and neglect by legislation. But, protection against destructive agents is essentially left to the custodians of historic buildings to manage. Advantageous advice from insurance organisations can be sought.

Now that an outline of the range of threats has been presented, the focus for the remainder of this chapter is fire, the 'threat agent' considered to have the potential to cause the most severe damage to historic fabric and content. The question that is how posed is: why are historic buildings so vulnerable to fire?

2.5 The specific threat from fire

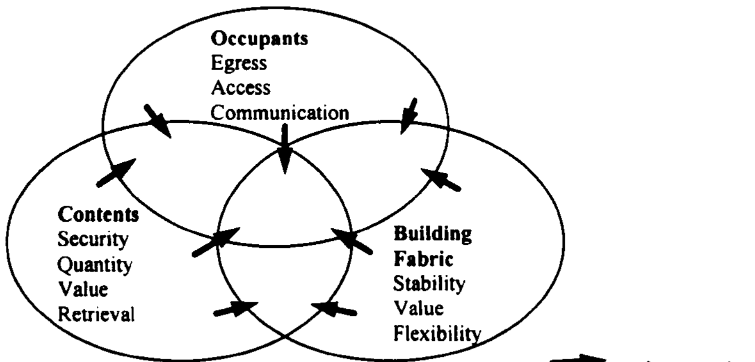
The complex environment present in most historic buildings, coupled with their unique structural arrangements make historic buildings specifically exposed to the threat of fire.

2.5.1 The complex environment of historic buildings

Historic buildings constitute a complex environment with regard to the building fabric, contents and occupants in terms of property usage and management[40]. This is created by the necessity to balance the need for such buildings to be kept in viable economic use, [as discussed in section 2.1.1] against the requirement to protect and preserve often sensitive fabric and content from attack by agents of destruction and decay [as discussed in section 2.4].

The effective management of fire safety requires the sympathetic integration of these components illustrated in figure 2.2. For example, the flexibility of the building fabric not only interacts with the access component of the occupants element, but also with occupancy egress under emergency conditions. Consequently, a two dimensional solution to this problem is required[41]. A further example illustrates the need for a three dimensional solution. The effective retrieval of content interacts not only with the access routes available but also with the stability of the structural building fabric [this integrating notion is further explored in the hierarchy of fire safety in chapter seven].

Figure 2.2: Notion of the complex environment created by historic buildings



2.5.2 Vulnerability of historic buildings

Historic buildings are vulnerable to the threat of fire as their construction and organisation can incorporate features which can assist the rapid development and spread of fire. This can include exposed timber floor structures, walls lined internally with combustible materials and roofs of thatch or timber shingles. Fire can spread rapidly through hidden voids, in floors, walls and open roofs or other voids in the building fabric for example; bell pull systems, gas and water pipes, drainage, electricity, ventilation, lift shafts, chimneys and flues. The common practice in seventeenth and eighteenth century buildings of providing openings in masonry walls twice as wide as the final door, as the exact position was not confirmed at the time of the erection of the masonry wall, is a typical example of a hidden danger specific to historic buildings[42]. Poor maintenance can create further voids due to timber shrinkage or fungal and insect attack which would allow the rapid movement of fire and the quick charring of timber. Further weaknesses in historic buildings are caused by later piecemeal and uninformed ad-hoc repairs and alterations[43].

The accommodation of facilities for the provision of lighting, heating, ventilation and other utility services can also enable rapid fire spread. The advent of electric power for lighting and mechanically-aided forms of heating and environmental control can now make the original in-built facilities redundant. As the modern service facilities are much smaller than the originals, redundant voids have been created, such as redundant boiler rooms, oil storage tanks and extensive brick or stone built ventilation flues and passages.

The often highly intricate, ornate nature of combustible material in historic buildings also adds to the vulnerability of historic fabric and content. The 'state of division' [see glossary for definition] of the material presents a large surface area which promotes both rapid fire spread during a fire and additional problems of cleaning and restoring such fabric [this is further discussed in chapter four and eight].

In addition, historic buildings are particularly attractive targets for theft and vandalism, which does unfortunately lead to incidences of arson.

2.5.3 Threat of fire during maintenance and refurbishment activities

Statistics show that approximately 10% of fires in historic buildings are caused by the consequence or direct careless activities of workmen[44]. During construction, buildings are generally more vulnerable to fire, regardless of building type or construction method, than when completed. Fires cause severe damage to buildings under construction because of the lack of structural members; non-applied fire-resistive materials; the open exposed condition of the structure, as well as the presence of combustible building material. There are further threats if during the refurbishment the building or part of it is still being used. Fire is likely to spread more rapidly because of the absence or impairment of fire suppression and detection systems. The temporary removal of structural protection and the presence of combustible building materials all add to the risk.

The specific threats from fire caused by the operating practices of building contractors, and measures to minimise the threats are examined in detail in the article: *Managing the Risk of Fire During the Maintenance and Refurbishment of Historic Buildings* written by the author [appendix A3].

2.6 Summary

Historic buildings are those which are deemed to have historical, architectural, or cultural significance. The range of historic buildings is vast representing examples of most types of buildings. Today the survival of such buildings hinges on the need to ensure that they are capable of modern usage, either in the original function they were designed for, in an alternative use or maintained by a charitable organisation as a tourist attraction.

There is overwhelming support for the need to preserve historic buildings on the grounds of educational, historical, aesthetic and commercial reasons. In addition, the value of historic fabric and content has been shown to be considerably more than just the monetary resale value of the property.

This in turn, requires an effective approach to the preservation of valuable, historic fabric and content. We exist in an environment which continuously threatens to deteriorate or destroy our building fabric. The principle of prevention is identified as being the method of intervention most appropriate to the prevention of both the agents of decay and destruction.

We can apply an array of measures to protect historic buildings. Acts of legislation, incentives from insurance organisations and the physical measures themselves all contribute to reducing the risk of agent attacks. For the agents of decay, effective maintenance programmes can control their risk quite readily. However, for those agents of destruction ['instant action threats'] the risk of the threat occurring can never be totally eliminated.

Fire has been shown to present the most severe threat to the fabric and content of historic buildings. The destruction, when it occurs is extremely swift, the damage caused is often severe with fabric and content being totally destroyed and the indirect damage from smoke and water can also be significant. In addition, the complex environment present in most historic buildings, coupled with their unique structural arrangements make historic buildings specifically exposed to the threat of fire.

As fire has the potential to cause total destruction, with the resulting loss of irreplaceable heritage and financial loss, an investigation into how the threat of fire can be controlled is warranted.

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CHAPTER THREE

AN EXAMINATION OF PARISH CHURCHES

3. AN EXAMINATION OF PARISH CHURCHES

3.0 Introduction

Further to the examination of threats to historic buildings as a generic body of buildings, this chapter describes the route taken to the selection of the 'unique occupancy' historic building type, parish churches, which forms the focus of this thesis. The ecclesiastical estate of The Church of England is initially reviewed and the value of the fabric and content of parish churches explored. This chapter then undertakes a comprehensive building evaluation, introducing the reader to the key aspects of the structure and function of parish churches. The specific fire threat to parish churches is demonstrated and a need for a fire safety evaluation procedure is postulated.

3.1 'Unique occupancy' selection

In chapter two the broad range of historic building types have been illustrated and evidence has been presented to indicate that historic buildings can exhibit characteristics which makes them particularly vulnerable to destruction by fire. The spectrum of research required to address this problem on a generic historic building basis, however, is too large for one thesis.

Before the investigation is taken further the scope of the research is narrowed to one historic building type. The criteria for the selection of this 'unique occupancy' is made on the grounds of the frequency of fire incidents occurring.

3.1.1 The selection of parish churches

A review of the frequency of fires in historic buildings using the national fire incident statistics published by the Home Office, is not possible as the building type categorisations used, do not specifically identify historic buildings. Instead, data from the Fire Protection Association fire records are used.

Table 3.1 shows fires in historic buildings which have caused a loss of more than £250,000 between 1991 and 1995 for England, Wales and Scotland.

Table 3.1: Serious fires in historic buildings causing losses of £250,000 plus 1991-1995[1] [England, Wales and Scotland]

Building type	Number	Estimated Loss (£m)	Percentage
Churches	12	8 345 377	[13%]
Houses	6	11 458 000	[17%]
Castle	1	40 000 000	[60%]
School	1	3 000 000	[4%]
Hospital	1	350 000	[0.5%]
Pier	1	3 000 000	[4%]
Public house	1	300 000	[0.5%]

It can be seen that the incidences of fires in historic churches contributes for over 50% of historic building fires [with a greater loss than £250 000] during that four year period. In monetary loss terms it only accounts for 13%, but this is largely due to the Windsor Castle fire which cost an exceptional £40 000 000. If that figure is removed from the equation then church fire loss contribution increases to 37%.

If it is considered that there are approximately 12,000 listed Anglican churches in England[2], plus approximately another 3,000 listed churches used by other denominations, [estimate made by the author] historic churches account for approximately 3% of the total historic building stock of about 500,000 [see section2.1.1].

Two important points can be extrapolated from these rather general figures. Firstly, that for a group of historic buildings that only account for 3% of the total, there has been a much higher number of fire incidents than would be expected. [The amount of loss expected from 3% of the total historic building stock, using the figure about, is one serious fire incident per year and approximately a £50,000 loss]. Secondly, to achieve a significant reduction in historic building fire incidents attention needs to be focused on churches before any other historic building type.

The cost of reported fire loss in churches is more accurately portrayed in statistics published by the Ecclesiastical Insurance Group [EIG], the leading ecclesiastical insurance organisation who insure 95% of Anglican churches in England and Wales. As can be seen in table 3.2 the average cost per year of all fires is £5.3 million [these include both historic and modern churches].

Table 3.2: Anglican churches - total cost of reported fire losses[3]

Year	Total cost (£m)	
1990	3.0	
1991	5.7	
1992	6.4	
1993	5.5	
1994	5.9	
Total	**26.5**	Average per year = £5.3 million

Further statistics from the EIG show that one in four churches can expect to suffer from fire, theft or vandalism over a twelve month period. This can be translated into the alarming figure that approximately seventeen Anglican churches are attacked each day[4].

Discussions with fire prevention officers[5] confirmed the finding of these statistics. For example south east London in 1995 had on average one serious church fire each month[6]. On this basis parish churches are selected as the focus 'unique occupancy'.

The investigation into suitable statistics revealed the complex scope of buildings that constitute a church and the broad range of buildings which are classified as places of worship. So it is considered important firstly, to clarify the terms 'parish' and 'church' within the context of a place of worship as interpreted in this thesis.

3.1.2 Parish churches as places of worship

The term 'place of worship' does not so much describe the type of building but rather the activity that is performed inside the building. So in terms of building type, the range is considerable, depending on the religious denomination, the age of the building and whether the building has been converted from a previous use or built for the purpose of worship.

Today in the UK we live in a multi-racial, multi-cultural and hence a multi-religious society. Religious denominations and groups own and hire a multitude of different buildings in which acts of worship are conducted, ranging from converted living rooms to grand cathedrals. In addition to the type of building, the title for the place of worship varies between the faiths [see table 3.3]. In each case the building is required to be certified as a place of worship or in the case of the Church of England and Wales registered as a place of worship[7] [see table 3.4].

Table 3.3: Classification of places of worship

Places of worship
Buddhist temple
Christian church and cathedral
Hindu mandir
Jain temple
Jewish synagogue
Muslim mosque
Sikh gurdwara

Table 3.4: Total number of places of worship in England and Wales[8]

Places of worship	Number
Certified places of worship	
Christian	29,500
Other faiths	1,500
Registered places of worship	16,500
Total	**47,500**

From the identified list of places of worship [table 3.3], we traditionally associate a church as the principal place of worship in the UK, within which the act of Christian worship has been conducted for over 1,000 years. However, the title, church, today consists in itself, of a wide range of building types, specifically those buildings used by the non-conformist denominations. This thesis focuses on a specific subset of churches, Anglican parish churches. [A parish being the district within reasonable distance of a church laid down by the Church of England. The boundary of a parish differs entirely from that of a town or village]. As detailed in table 3.5, Anglican parish churches comprise 35% of all places of worship in England and Wales and as a collection of buildings present a definable common form [this is discussed further in section 3.3.1].

It is important at this point to also clarify the terms 'historic church' and 'modern church'. For the sake of this thesis a 'historic church' is considered to have been built before 1914 [whether listed or not]. The term 'parish church' will be used throughout the thesis and will be assumed to be historic, but it can be considered that the principles and issues presented can be readily applied to modern churches unless stated otherwise.

Table 3.5: Religious denominations and places of worship [for England and Wales]

Denomination	Number of active members[9]	Number of places of worship[10]
Christian Church of England Church of Wales	**37,600,000**	**16,500** [15,000] [1,500]
Christian non-conformist Roman Catholic Methodist Baptist Union of GB United Reform Church Congregationalist Calvinistic Methodists Brethren Salvation Army Unitarian Quaker Jehovah's Witnesses Others		**29,500**
Other faiths Jewish Muslim Others eastern faiths: Sikh, Hindu, Buddhist, Jain, Baha'i etc.	**2,600,000** [300,000] [1,100,000] [1,200,000]	**1,500** [354] [487] [659]
Total	**40,200,000**	**47,500**

3.2 Ecclesiastical estate

3.2.1 The Church of England

The estate of the Church of England consists of just over 15,000 churches in active use. They are divided across 43 dioceses with the largest being Oxford with 820 churches and the smallest, Sodor and Man, with 44. In addition, there are 43 Anglican Cathedrals, one in each diocese, which range in size from St Paul's in London, York Minster, Durham and Salisbury to the smaller parish church type cathedrals found in, for example, Leicester and Birmingham. There are also two 'royal peculiars' in Westminster Abbey and St George's Chapel, Windsor[11]. 75% of the estate has a statutory listing, 16% [approximately 2400] churches are grade I and considered to be buildings of exceptional interest[12].

The management structure for the Church of England is shown in appendix B1. The Archbishop of Canterbury, currently The Most Reverend George Carey, has the grand title of Primate of all England. The hierarchy of the spiritual ministry then consists of the Archbishop of York, the Diocesan Bishops, Archdeacons, Deans and then parish clergy. As an organisation, the Church of England is managed by a system of Synodical government. At present the church operates on four tiers of management; the parochial parish council, deanery, diocesan and general synod. Various commissions, including most recently the Turnbull Commission[13] have reported on approaches to change the ageing management structure into a more modern, cost effective structure. However, whether such recommendations are to be implemented is not yet known.

3.2.2 Fire safety in Anglican cathedrals

As a prelude to the examination of parish churches, the investigation began with a study into fire safety in cathedrals. The work included an investigation into the types and approaches to preventing fires and the methods of suppression employed in a small, medium and large cathedral [Leicester, Southwell and Lincoln]. The second series of case studies were under taken at four large cathedrals [York, Ely, Norwich and Lincoln] to review the range of management structures currently in place. A national picture of the standard of fire safety in Anglican cathedrals was also gained by reviewing and abstracting data from the files of the Ecclesiastical Insurance Group. The results of this work are presented in two published articles. *Protecting the Fabric and Content of Historic Cathedrals Against Fire*, and *The Protection of Cathedrals against Fire: A Review of Insurance Data.* [see appendix B2]

The work essentially, concluded that the number of incidences of fire in cathedrals is, in fact, small and that threats of fabric damage from other destructive agents is greater, but most importantly, the situation is not the same for churches. Statistics show the number of fire incidences in churches to be high as previously discussed in section 3.1.1.

This outcome mirrored the conclusions of an English Heritage[14] research project, conducted under commission by Warrington Fire Research Consultants into fire safety in cathedrals.

3.3 Parish church building evaluation

The investigation into the issues of fire safety in parish churches starts with a comprehensive review of the structure, layout, use and management of the selected 'unique occupancy' building type.

3.3.1 The structural development of parish churches

Parish churches are essentially single cell buildings (often very old), built to accommodate acts of worship. They range from great town churches to small rural village churches but all exhibit the feature of loftiness and spacious undivided interiors[15].

There are only a handful of churches remaining from the Saxon and Norman periods [pre thirteenth century]. The majority of churches were constructed in the Gothic style of the thirteenth, fourteenth and fifteenth centuries. These are recognised as typifying the English village church. Many of these have undergone major renovation and repairs by the Victorians. These repairs are now in some cases coming to the end of their natural life span. Apart from localised construction in the Georgian (or classical) style, mostly in London after the Great Fire, no further major church construction took place until the nineteenth century which saw a proliferation, particularly in towns and cities, of large brick churches.

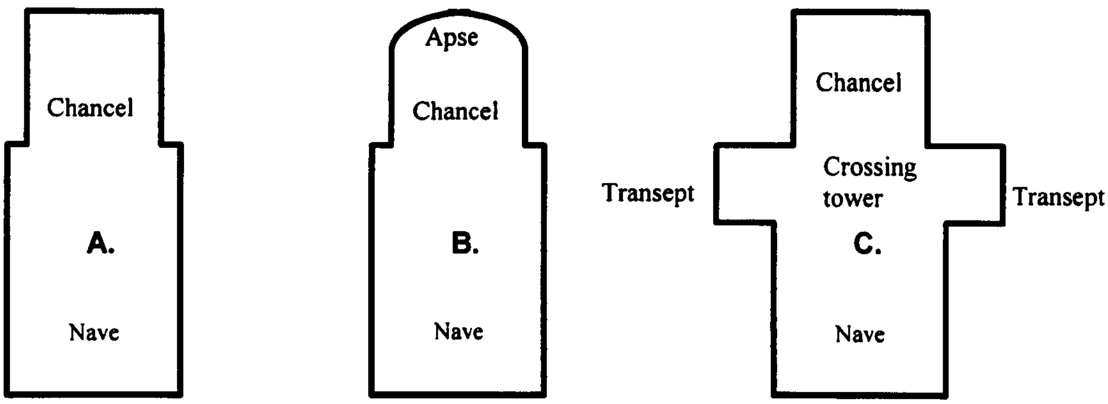
Generally parish churches were constructed with what materials were available locally. There is considerable regional variation, for example there are cases, mostly in stoneless counties such as Essex, of timber towers, belfries, spires and porches, but typically medieval churches were constructed of stone rubble filled walls either exposed or plastered and white washed internally, exposed timber roofs with lead or tile covering and solid or raised timber ground floors. Fixtures and fittings are also predominately constructed from wood. A more detailed overview of materials used in the construction of churches is contained in appendix B3.

The construction of parish churches has evolved according to liturgical requirements and available funding. The twelfth century saw the true transition from Anglo-Saxon to medieval England. It was a period during which the parish church nave [see glossary for explanation of liturgical terminology] evolved into its final rectangular form. Generally about seven metres wide by twenty metres long for the average parish church[16]. It is from this period that the individual developments of all parish churches can be traced. In this thesis it forms the point of initial reference.

The footprint of parish churches in every case may ultimately be traced back to one of three fundamental types in use in the twelfth century[17] and these are:

- The nave and chancel [square end] [A]
- The nave and chancel [apsidal end] [B]
- The cross church with nave, transepts, chancel and central lantern-tower [C]

Figure 3.1: Plan of three fundamental church layouts



Of the above three layouts the type B. did not continue as a permanent form[18] and type C. is generally typical of larger urban churches and cathedrals. The majority of parish churches have developed from the initial nave and square ended chancel layout, and shall be used for the purpose of explanation throughout the thesis.

From the initial basic twelfth century layout each parish church has undergone a unique evolutionary process to reach its full development. Some churches grew steadily throughout the medieval period as congregational sizes increased, while others received only slight alterations such as a new door, window or arch. The wealth within the parish influenced the sizes and quality of the church. In each case the individual developments can be considered to be for one or a combination of the following reasons:

- Structural necessity: alteration on an account of a structural necessity consisted of the strengthening of arcade arches or the strengthening of the tower to include another level or spire.
- Functional requirement: An extension for a vestry or the addition of an aisle to give extra seating space.

- Aesthetic improvement: A chapel paid for by a local wealthy family, or the addition of a spire.

Today each church is a blend or hybrid, of spaces generated from the base footprint of one of the previously noted fundamental types.

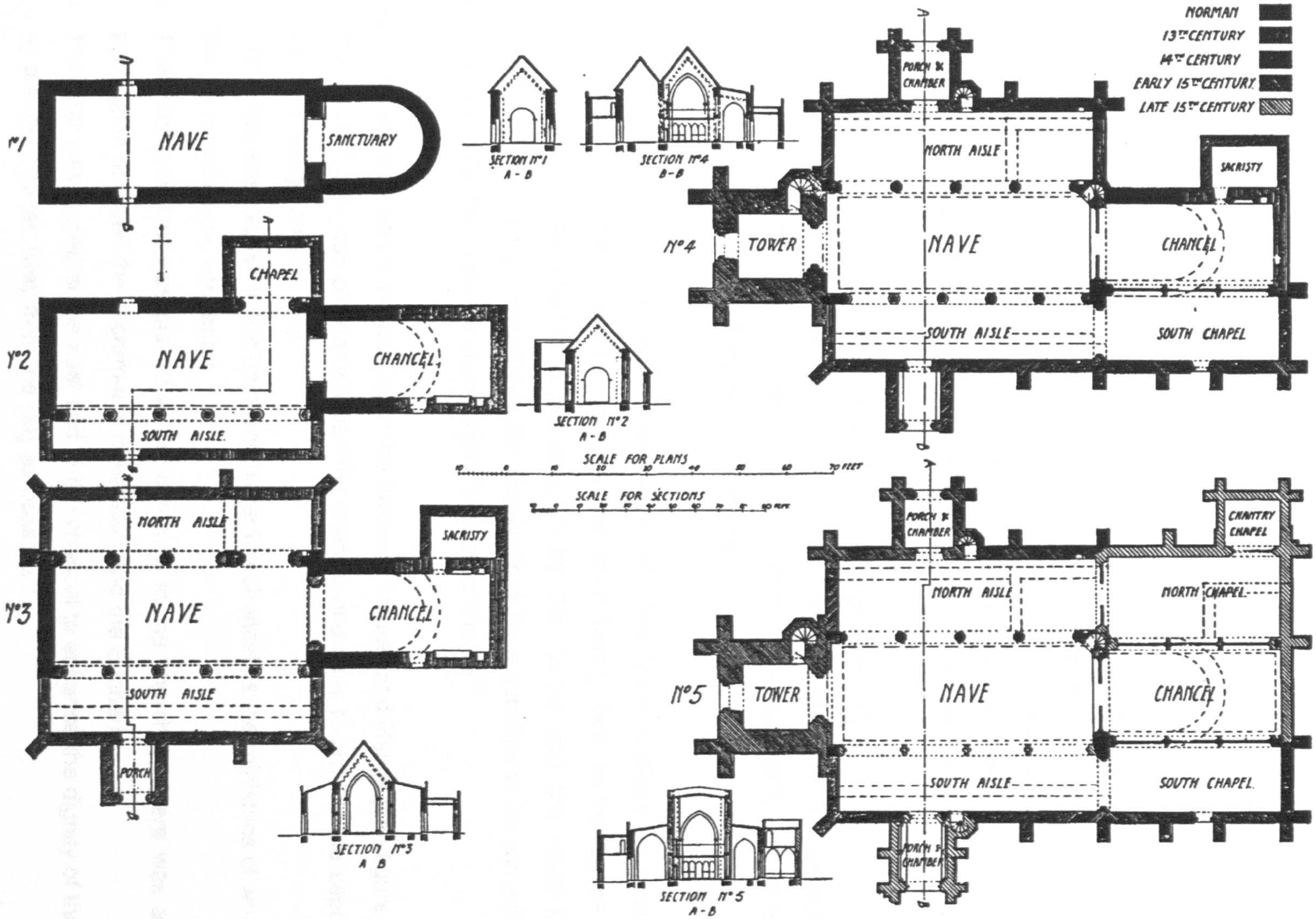
An appreciation of the typical metamorphosis in medieval churches can be gained from figure 3.2. The example is only a typical evolution of a parish church, but clearly demonstrates how the size and orientation of the original nave and chancel strongly dictate the size and form of the surviving building.

Evolutionary steps:

- In the thirteenth century the apse was removed and lengthened to form a square ended chancel. A south aisle was added to accommodate a growing population, while on the north side of the nave a wealthy benefactor provided funds to build a chapel.
- In the fourteenth century the chapel was extended into a north aisle. The south aisle was widened to provide more accommodation and an additional altar. A south porch was built, a sacristy added to the chancel and the old twelfth century chancel arch was replaced with a wider one.
- The development during the fifteenth century was most extensive. The parish undertook the erection of the tower, while a wealthy benefactor provided funds for the rebuilding of the north aisle and the adding of a north porch with a chamber over it, a south chapel on the chancel was built, a screen with loft and rood was build between the nave and chancel. A north chapel was built from the chancel and a chantry chapel off the north-east side, a chamber was built over the south porch and finally a clerestory was added to the nave.

The reformation signalled the end of parish church development [although the interiors changed significantly. See section 3.3.2].

Figure 3.2: Typical parish church development from the twelfth to the end of the fifteenth century[19]



In addition, church developments were further influenced by the tradition of laying out churches on an east-west axis. The reason for the east-west axis, however, is not fully understood and medieval theologians had their own theories for facing east when worshipping. William Durandus, Bishop of Mende from 1285 to 1296 presented the following reasons: 'The east is the image of Christ who, like the rising sun, lighteth every man that cometh into the world' and 'our souls be thereby taught to turn themselves to the things that are most desirable'[20]. There are examples, however, where churches were orientated to accommodate the site available. Especially many nineteenth and twenty century churches built in confined urban sites have rejected the orientation completely. For example the new Coventry Cathedral was built at a right angles to the old and has its chancel facing north. It is only during this century and the development of contemporary designs that church layouts have really started to break with ecclesiastical tradition. [The design and construction of modern churches is not covered in this thesis].

3.3.2 The development of church layouts and liturgical furniture

Church doctrine throughout history has always been expressed in church architecture. It has generally been the case that the development of churches externally was dictated by the requirements of the use of the space internally.

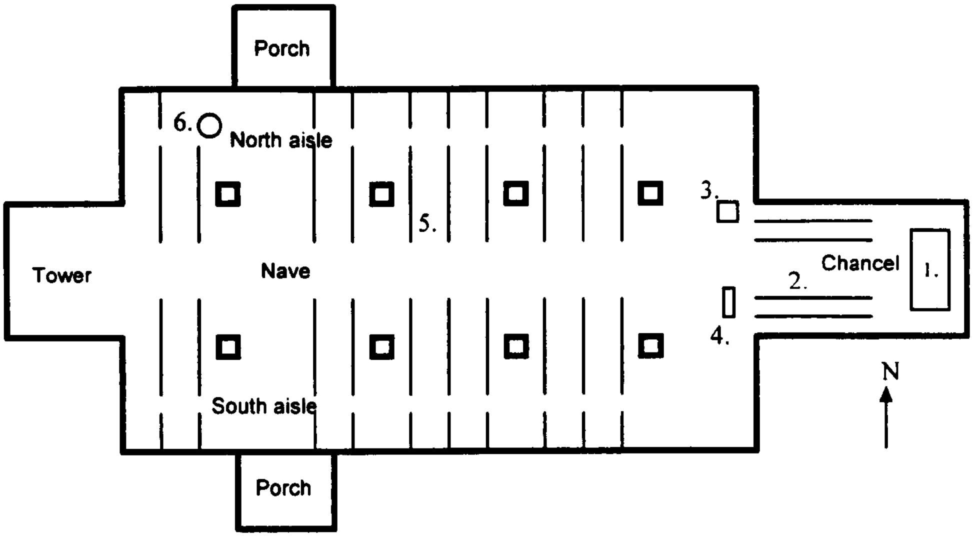
Twelfth century medieval churches were essentially two-space edifices [as detailed in section 3.3.1]. The clergy and the congregation each having their defined space in the sacred edifice[21]. The chancel was occupied by the clergy and the nave by the congregation. The clergy considered the Eucharist to be a sacrifice to be witnessed by the profane laity, rather than a communion feast to be shared[22].

Such division defined the positioning of the following fixtures and fittings [see figure 3.3]:

- The rood screen was placed between the chancel and nave to provide the separation between clergy and the laity.
- The pulpit was located in the nave and never the chancel as the ministries of word and the sacrament were kept apart.
- The baptismal font was placed at the entrance to the church so there was a clear separation between the sacraments of baptism and the Eucharist.
- The altar was placed at the east end of the chancel to enhance the dignity of the altar by placing it as far away from the laity as possible[23].
- The pews were placed throughout the nave and aisles to accommodate the laity.

As Christian doctrines have changed over the centuries spatial layouts have evolved from the initial undivided two-space edifice. Today, the traditional arrangement of liturgical furniture generally consists of the following [see figure 3.3]

Figure 3.3: Typical layouts of liturgical furniture



Key:
1. Altar
2. Choir stalls
3. Pulpit
4. Lectern
5. Pews
6. Font
Note: Organ and vestry not located

Research by the author [see chapter six for the methodology] has shown that the position of two specific facilities of a church layout, however, can not be predicted. As shown in table 3.7 the position of the organ and vestry area varies depending on the spaces and resources available, although a location close to the chancel is the preferred position for both the organ and vestry in the majority of cases.

Table 3.6: Location of organ and vestry facilities [Leicester Diocese church survey, see section 6.3.1]

Locations of the organ:		Location of the vestry:	
Chancel (with the casement in a transept extension or aisle)	56%	Extension/room (off the chancel)	38%
Nave	12%	Vestry extension (not off the chancel)	19%
South aisle	6%	Part of the nave	4%
North aisle	15%	Part of the north aisle	11%
Tower ground floor	2%	Part of the south aisle	5%
Tower first floor/balcony	6%	Tower ground floor	14%
Other location	2%	Tower first floor	2%
		Other locations	5%

This simple explanation of a typical liturgical layout, however, is complicated when it is considered that some churches are used for more than a liturgical assembly. Many churches today have space that can be liberated for multi-purpose use. Davis[24] describes an example of re-ordering that would require the construction of an extension in a westerly direction from the tower to act as a secular hall. This was rethought, however, because there would be a dichotomy between sacred and secular activities. The final solution involved removing the fixed pews and have light stacking chairs which could be removed when the space was to be used for secular activities.

So, in terms of liturgical layout, a traditional arrangement has been presented, and in that context the fixtures and fittings can be claimed to be fairly standardised and their locations predictable except for the organ and vestry area. But the multi-purpose re-ordered parish church does not conform to this model and there needs to be an awareness of this.

3.3.3 Building use

The primary function of parish churches is to serve as places of assembly, in which acts of worship are conducted. But in addition, parish churches can accommodate a complex arrangement of other secular and support activities [as detailed in table 3.7] [the results shown in this section are from a survey of Leicester diocese churches. See chapter six for methodology]. In such a context churches must be viewed as multi-purpose buildings.

It is appreciated that some churches today are deconsecrated and are declared redundant or accommodate alternative uses, for example residential accommodation, museums and retail outlets. Such churches are not considered in this thesis.

Table 3.7: Secular and support activities to services of worship [Leicester Diocese church survey, see section 6.3.1]

Activities	Percentage
Cleaning [brass cleaning, flower arranging]	95%
Concerts	60%
Church functions [meetings, festivals, fairs]	59%
Organ practice	43%
Choir practice	38%
Exhibitions	23%
Outside organisation meetings/functions	19%
Bell ringing practice	9%
Sunday school/pram clubs	6%
Coffee mornings	2%
Guided tours [educational visits]	2%

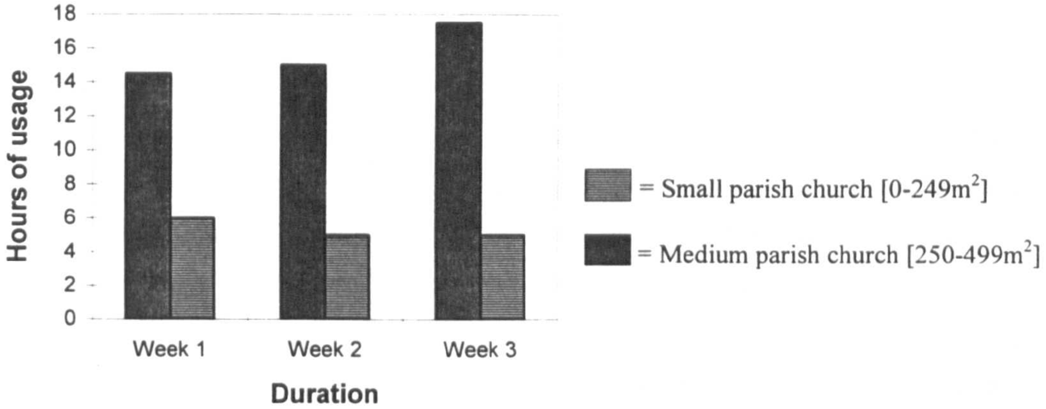
The hours of usage occupation for parish churches varies. The variation is most significant when separating urban/suburban churches from rural and isolated churches. As shown in table 3.8, churches in rural locations are used for less than five hours per week in 82% of cases, which suggests that very few secular activities are undertaken, while in the case of urban and suburban churches 76% are used for more than five hours per week showing such churches to have a greater usage factor.

Table 3.8: The average hours of church occupation per week [Leicester Diocese church survey, see section 6.3.1]

Hours	Percentage of churches surveyed: urban/suburban	Percentage of churches surveyed: rural/isolated
<2hrs	6%	47%
2 - <5hrs	18%	35%
5 - <10hrs	26%	14%
10 - <20hrs	29%	4%
>20hrs	21%	0%

As a means of gauging in more detail the typical time in use of parish churches two churches were asked to keep a record of the buildings use for a three week period. One church being a small rural church and the other a medium size parish church in a city suburb. Usage times are shown in figure 3.4. The data is in appendix B4.

Figure 3.4: Church usage study



If these two usage profiles are averaged the unoccupied periods for the small parish church is 97% and the medium parish church is 90%. In addition, churches may be unoccupied and left open for the general public to access at will. Survey data revealed that 20% of churches were left unlocked, the majority [90%] of those being rural churches.

It has been mentioned that parish churches today are a hybrid of spaces, the principal space being the main worship area. In addition, various supporting facilities are typically accommodated as detailed below.

Table 3.9: Typical space usage in addition to the main worship area [Leicester Diocese church survey, see section 6.3.1]

Facilities	Description
Porch(es)	Space through which the worship area is entered
Vestry area	Room or space in which the vestments are stored
Meeting room or space	Room or space laid out for meetings, Sunday school etc.
Sacristy or office	Generally a lockable room which can act as an office
Boiler room	Room above or below ground in which the boiler is located
Bell ringing chamber	Room or space where the bells are rung
Clock chamber	Generally the middle level of the tower in which the clock casement is housed
Bell chamber	The room which houses the bells and bell frame

3.3.4 Parish church management

Each parish church is under the individual control of a parochial church council [PCC] made up of the vicar, two church wardens and other elected members. The Parochial Church Council (Powers) Measures 1956 defines the role of the PCC as 'to co-operate with the incumbent in promoting in the parish the whole mission of the church, pastoral, evangelistic, social and ecumenical'.

It is the responsibility of each PCC to ensure the well-being and protection of its own building. PCC are entirely autonomous in this function. In terms of building management in general and fire safety specifically, advice is available from the sources as shown in figure 3.5. In terms of funding available, each PCC is given an annual sum from the Church of England, of which 50% goes to the diocese, approximately 20% is spent on the building insurance premium, leaving a typical parish church approximately £1,500 to spend annually, on the building maintenance of often grade I listed property. Any further funds have to be raised through donations or fund raising events.

PCC's, are often very fluid in their structure. Vicars come and go, each bringing different levels of emphasis on a variety of topics. Churchwardens are elected for only a one year period, although some do serve for longer. It makes the gaining of a continuity of approach very difficult.

Elected members of PCC's bring to the membership many different skills, but often not the building maintenance knowledge needed to effectively manage the preservation of unique historic fabric. Survey figures [see chapter six for methodology] show that out of a 128 churches in the Leicester Diocese only 37% have any member with commercial experience in building maintenance, and only 17% with a member with commercial experience in fire safety management.

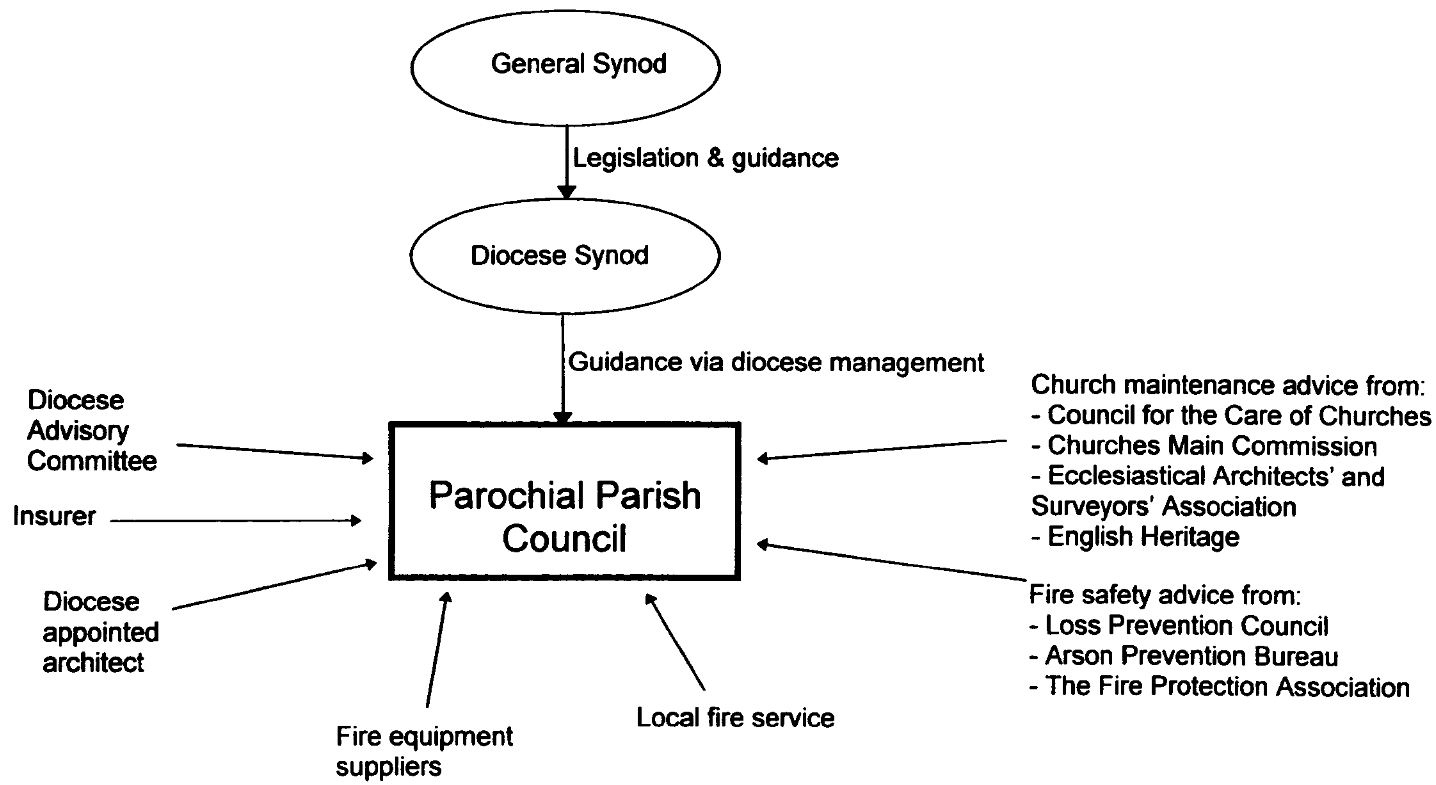
3.4 The value of parish churches

In section 2.1.3 an introductory discussion was presented in respect to considering how the value of historic property can be quantified. Here that discussion is expanded in the context of parish churches.

3.4.1 Their social significance

Arguably, England contains the greatest collection, in terms of number and antiquity of ancient parish churches in the world. Their age, their history and their appearance, the quality of materials and craftsmanship, all combine to make the fabric itself irreplaceable. The diversity of their structures and interiors varies widely from great town churches to

Figure 3.5: Building maintenance and fire safety management: information and advice channels



small village churches. Their locality and the readily available construction materials add to their individuality.

The study of historic churches has been of national interest for many years with numerous accounts of the development of English church architecture. Thomas Rickman, a Liverpool architect was perhaps the first to write authoritatively upon the subject in 1817[25]. Since then, commentators have continued to fill their books with endless superlatives about the splendour of the English parish church. For example, 'the parish churches of England provide the finest and most characteristic contribution to mediaeval art'....they stand as a vast series of grand monuments of English vernacular craftsmanship'[26]. But it is perhaps the work of Nikolaus Pevsner[27] and his series of books documenting the buildings of England which today are regarded as the most respected assessment of the historical value and architectural significance of parish churches.

Parish churches today perform a diverse range of functions. To the present parishioners they continue to provide a home for their acts of worship, in addition, many parish churches provide accommodation for other religious and secular activities [as identified in section 3.3.3]. Parish churches also have another role, that of shrine or relic. They represent for parishioners a shrine to their local history, while for the nation as a whole they are a record of the country's past. Throughout their history parish churches have been the repositories of splendid works of art and illustrative of the best efforts of craftsmen in skills ranging from stonemasonry and wood carving through to embroidery, gilding and painting. Such credentials mean that a simple monetary evaluation of loss is not appropriate in the context of parish churches. The intrinsic emotional, cultural and use values [see section 2.1.3] make a significant contribution to the overall value of parish churches.

3.4.2 The implication of loss from fire

As previously discussed the quantification of intrinsic value is beyond the scope of this thesis, but consideration is given here to the potential implications of the loss of historic fabric and content as a means of evaluating the intrinsic value of parish churches. Such a loss would not only be a loss in both human and economic terms, but the loss of historic property that forms part of our cultural heritage can mean the loss of a resource which is finite and irreplaceable.

Two categorises of loss can be identified, that of the facility or functional loss and secondly that of material loss in terms of heritage and culture. In the first category the loss of a place to worship is the immediate concern and will involve a temporary relocation. This may be the shared use of an adjoining parish church or the adaptation of a church hall as in the case of the fire at St Phillip's, Evington, Leicester [see section 3.5]. The scale of this first problem will depend on the size of the regular congregation and the availability of suitable alternative accommodation. The Venable George Cassidy[28], who has had two major church fires in his diocese in the last ten years [St Peter's, Eaton Square, London and St Mary-at-Hill, London] notes that it is important at the first available moment after the disaster to articulate to the congregation that the people of God are the church and the building was their home and while the latter may have been lost the church nevertheless remains intact. The immediate period after a fire disaster requires decisive leadership to keep the church together, to devise effective ways of communicating policy to not only regular members but also to fringe members and organisations that may use the church facility. If important administrative papers are lost in the fire this could be made even more challenging.

The greatest challenge lies in the cleaning up, the making safe of the remains of the building, setting out the insurance claim and deciding on the approach to restoration. Experience has shown this to be a long and often unsettling task as individuals work long hours and decisions regarding the churches future unfortunately will never please everyone.

Through the experience of the two previously mentioned London fires two positive outcomes were noted. Firstly, both church leaders commented that there was a great sense of pulling together and people having a sense of belonging. The disasters also provided the opportunity for reordering and exciting initiatives. The St Peter's, Eaton Square church experienced a growth of 40% in the congregation following its restoration. These two cases clearly illustrate that the loss of the property does not necessarily mean the loss of the church and its community.

Turning now to the second category, historic and cultural value, it has been previously discussed that the fabric and content of churches can consist of irreplaceable national treasures. Such treasures have a loss felt factor which can be expressed in terms of how widely the loss would be felt depending on the uniqueness of the item in question. For example, the timber vaulted ceiling of the south transept of York Minster was unique and its loss was felt internationally, while the loss from fire of the vestry and organ loft in the ninteenth century church of St Phillip's, Leicester had very little loss impact in terms of historical importance as the fabric and content were ordinary.

To demonstrate the application of the loss felt factor the results from a section of the Leicester Diocese church survey are shown. Initially, fabric and content historic value classifications were devised [see table 3.10].

Table 3.10: Classification of fabric and content historical and architectural merit

Classification	Description
Unique	of international importance
Rare	of national importance
Important	at a regional level
Valuable	at a local level
Ordinary	many other examples

As a sample measure of the range and types of items that are considered of historical and architectural merit incumbents in the Leicester Diocese were asked to indicate what treasures were in their churches.

Out of 259 sections of fabric identified to have some historical and architectural merit (from 86 churches) the incumbents judged the fabric to be of the following degrees of importance [table 3.11].

Table 3.11: Classification of fabric [Leicester Diocese church survey, see section 6.3.1]

Classification	Percentage
Unique	1%
Rare	11%
Important	27%
Valuable	41%
Ordinary	20%

And out of 334 items of fixed or removable content identified to have some historical and architectural merit (from 95 churches) the incumbents judged the content to be of the following degrees of importance [table 3.12].

Table 3.12: Classification of content [Leicester Diocese church survey, see section 6.3.1]

Classification	Percentage
Unique	0.5%
Rare	12.5%
Important	28%
Valuable	37.5%
Ordinary	21.5%

Clearly, in the case of the churches surveyed they consist of or contain, very little unique fabric or content, the majority considered to be in the important or valuable category. The classification of fabric and content using such an approach can enable decisions to be made on the level, or limit, of loss acceptable. Such an approach presents one possible way of quantifying the intangible value.

3.5 Fires in parish churches

Attention is now given to fires which have occurred in parish churches and the problems and issues surrounding the management of fire safety.

3.5.1 Examples of fires

Fires have occurred in all types and sizes of churches. A list of serious church fires which have occurred over the past two decades are shown in chapter one. Incidents have happened in churches ranging from the internationally renowned to the locally valued facility as detailed below.

Table 3.13: Examples of church fires

Examples
Locally known church: The St Philips, Evington, Leicester, 1 January 1996 A fire started in the vestry of the red brick church constructed in 1920. It spread to the organ loft above and through the roof. The vestry was destroyed along with the organ. The rest of the church received considerable water and smoke damage. Three years later the parish are still using an adjoining village hall for worship and the church stands empty.
Nationally known church: St Mary at Hill, London, 10 May 1988 A fire started in the roof of the church from the heat of a blow torch igniting roofing material. The belltower and three quarters of the church was destroyed, the remainder sustained heat and smoke damage. The restored cost £3 million.
Internationally known church: York Minster, York, 9 July 1984 The south transept roof was devastated by fire, although the Rose Window survived. The fire is believed to have started by a lightning strike generating a phenomenon known as a 'side-flash'. The flash occurred within the roof space, splintering and igniting timbers and allowing fire to gain a hold without the knowledge of security staff on duty. The restoration cost £11 million.

Table 3.14: Fire safety in parish churches: problems and issues

The structure and layout of parish churches
• Although most churches are constructed of solid stone walls often over 600mm thick the ad-hoc methods of construction in previous centuries can make the building unstable in a fire. This is particularly true of clerestory extensions where the nave roof is raised to a higher level
• The construction itself can contribute to a fire for example due to there being no or little consideration given to compartmentation or fire stopping. Fires in church roofs are virtually impossible to stop as the void between roof and ceiling is generally very hard to access. This can be coupled with the fact that it was common for the void to be stuffed with straw for insulation
• The loftiness and spaciousness of churches and their large undivided areas ensure an ample supply of air to fuel a fire, while spires and towers may act as flues and provide the fire with a fierce draught
• Churches generally contain considerable amounts of combustible materials in their fabric and content. There is significant structural timberwork in roofs, floors, ceilings, pews, choir stalls, organs, panelling and wooden screens. Wax polishing can encourage woodwork to burn even more rapidly
• Churches are often sited in locations, where access for fire appliances many be restricted by boundary walls, lychgates, trees and burial grounds
• There is often a restricted water supply to churches. In some cases there may be no mains water, in others a static supply of any quantity may be some distance away
Parish churches and their usages
• Churches are left unoccupied for long periods. Most if not all serious fires have occurred in unoccupied churches
• During the day churches may be unoccupied and open to allow members of the general public to come and go at will
• Churches are often hired out to other organisations, who use the building without supervision
• Churches are expected to be able to accommodate a diverse range of community activities, ranging from small meeting groups to public concerts
The building's management
• Those entrusted with the responsibility for the safe keeping of churches are often unaware of their vulnerability or how the risks can be reduced. The building's stewardship is a voluntary pastime by people who have skills in other areas[31]
• A settled period of management is unlikely as elected members of PCC's only serve for one year. Although many are re-allocated it does not present a settled environment in which a continuity of approach can be easily deployed. This is further complicated by new members bringing with them differing levels of emphasis on a variety of topics
• PCC members and specifically church wardens receive no formal training in property management. They are often well intentioned amateurs

Table 3.14: Fire safety in parish churches: problems and issues [continued]

• PCC's manage the property maintenance on very low budgets. [There is no other estate responsible for such a large stock of historic buildings which manage their buildings in such a hands-off manner, with such minimal funds at their disposal]
• Where fire protection equipment has been installed lack of knowledge often means it can be poorly maintained and misused[32]
• Diverse management control across dioceses make the establishment of an overall fire safety management strategy impossible to enforce. The autonomous nature of PCC further hinders the situation

Three key issues present themselves from an overview of the problems: that of amateur management; the issue of limited funds available and the extreme sensitivity required in the installation of active and passive fire precaution measures.

A possible solution is the installation of an array of fire precaution measures, but in the case of parish churches this would not be acceptable on both financial and aesthetic grounds.

Clearly, the solution must start with the education and awareness of those who manage parish churches at both parish and diocesan level. Such a programme of education currently only exists in the form of available literature from organisations such as the Council for the Care of Churches, Loss Prevention Council, Arson Prevention Bureau and insurance organisations [as detailed in figure 3.5]. The second step, which is starting to occur in some of the larger churches of well intentioned parishes, is the development of suitable management systems and techniques. Such strategies require the PCC's to seek guidance from the local fire services and a qualified fire engineers. It is only then that the final step can be taken. to install suitable active and passive fire precaution measures.

Before deploying funds or implementing fire precautions an effective fire safety strategy must be developed to evaluate the existing fire risk and fire safety level in the building. Currently no systematic procedure for fire safety strategy development exists for churches. It is considered that the development of such a process would provide a major contribution to the prevention of fire and fire damage in churches as postulated in the hypothesis:

A formal system for the evaluation of fire safety in parish churches could be a valuable tool, offering, simple, repeatable techniques for assessment, an immediate appraisal of acceptability and a method for the rapid identification of deficiencies. This could facilitate the adoption of a suitable, cost effective fire safety strategy.

3.6 Summary

Churches have been shown to have a high occurrence of fires in comparison to other historic building types. Malicious actions (arson) accounts for a high proportion of church fires. It is considered that churches have become soft target for theft, vandalism and fire attacks and statistics from the EIG show there is currently no decline in the trend.

Parish churches are essentially single cell buildings consisting of a blend or hybrid of elemental spaces generated from the base structure of two fundamental forms: the nave and sanctuary or the cross church. They range from great town churches to small rural village churches but all exhibit the feature of loftiness and spacious undivided interiors.

Generally parish churches were constructed with what materials were available locally. There is considerable regional variation, for example there are cases, mostly in stoneless counties such as Essex, of timber towers, belfries, spires and porches, but typically medieval churches were constructed of stone rubble filled walls either exposed or plastered and white washed internally, exposed timber roofs with lead or tile covering and solid or raised timber ground floors. Fixtures and fittings are also predominately constructed from wood.

Most parish churches are shown to be multi-purpose buildings accommodating religious as well as secular activities. But in terms of liturgical layout, a traditional arrangement can be presented, and in that context the fixtures and fittings can be claimed to be fairly standardised and their locations predictable except for the organ and vestry area. The multi-purpose re-ordered parish church does not conform to this model, however.

It is the responsibility of each PCC to ensure the well-being and protection of its own building. PCCs are entirely autonomous in this function. The responsibility for building management in general and fire safety specifically is undertaken by well intentioned amateurs. Advice is available but no formal training is provided.

English parish churches as a collection present, arguably, the finest example of ancient parish churches in the world. At an individual level, their loss would be felt in terms of the loss of a facility. This being dependent on the intensity of the buildings usage and the availability of alternative accommodation, and in terms of the historic and cultural loss of the property. It is suggested that such loss could be categorised into the following: unique, rare, important, valuable, ordinary.

The review of the problems and issues regarding fire safety in churches, has resulted in the identification of the need for a procedure to evaluation the existing fire risk and fire safety level in church buildings. Such a tool would play a valuable role in aiding the custodians of churches in their management of fire safety. In addition, an evaluation tool would help to highlight the key problems and aid in the allocation of scarce resources to improve the fire safety provision where necessary. A contribution to the reduction of fires in churches and the protection of irreplaceable heritage would be achieved.

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CHAPTER FOUR

FIRE BEHAVIOUR IN PARISH CHURCHES

4. FIRE BEHAVIOUR IN PARISH CHURCHES

4.0 Introduction

This chapter initially undertakes a building fire performance evaluation which presents clear evidence on the expected performance of the chosen 'unique occupancy' in respect to fire prevention, ignition, fire growth and the application of fire safety precautions. A review of the fire risk to life, property and mission continuity in parish churches is then conducted.

4.1 Building fire performance evaluation

The thesis so far has evaluated firstly, the 'threat agents' that can cause harm to historic buildings and presented evidence to indicate that fire has the potential to cause the most severe damage and secondly, that the frequency of fire incidents in churches is currently greater than any other historic building type. An analysis of the construction, layout, use and management of parish churches [building evaluation] has concluded that a tool to aid management in the evaluation of the existing level of fire safety would be beneficial. Such a tool would need to evaluate not only the level of fire safety, but also the degree of importance the fabric and content of the property possesses.

The next step taken in this thesis is a building fire performance evaluation. Fire is a dynamic event and it is necessary to attempt to evaluate the behaviour of fire in parish churches and the behaviour of parish churches subject to fire. The analytical framework used for this evaluation is based on the framework presented in the Building Fire Performance Evaluation Methodology[1]. The evaluation is sub-divided into distinct components as shown in table 4.1.

This building fire performance evaluation combined with the building evaluation [conducted in chapter three] presents a complete picture of the 'unique occupancy' to enable fire safety performance to be evaluated in a coherent manner and communicated logically. For the purpose of this thesis the evaluation is undertaken, not on an individual building basis but on a typical generic parish church as illustrated in figure 3.2 [chapter three].

To provide a flavour of the causes and severity of church fires a further selection is summarised below. Examples of fires started deliberately include[29]:

- Two boys broke a rear window, climbed in, drank a large quantity of communion wine, lit the altar candles and set fire to a Nativity crib and piano. The fire spread with devastating speed destroying the floor, screen, organ and much of the roof. The damage was £400 000.
- An intruder set fire to paper and fabric in the vestry of the church destroying a substantial part of the historic church. The fire spread from the vestry into the main body of the church before it was discovered. Fire spread was accelerated by the presence of several butane gas cylinders. The damage was £400 000.

Fire started by other causes include[30]:

- A portable electric fire was left switched on in the sacristy on the ground floor after a cleaner had finished her work and left. Radiant heat from the fire ignited clothing hung on wall pegs nearby. Damage was estimated at £72 000.
- Workman had been treating the roof timbers for dry rot, using an oxy-acetylene gas torch to burn fungus from surrounding stonework. They extinguished the torch while they went for a tea break leaving the church empty. When they came back the roof was on fire. Damage was estimated at £72 000.
- Defective stonework inside the roof space allowed sparks from the boiler flue to ignite roof timbers. The roof of the church was completely destroyed and fittings and fixtures below were damaged by falling debris and water. Damage was estimated at £52 000.

3.5.2 Problems and issues

The building evaluation has presented a broad overview of the structure, use and management of parish churches. Utilising the noted information, it is possible to conduct a simple analysis to enable problems relating to fire safety in parish churches to be highlighted.

The broad outcome of the evaluation is that parish churches present a unique and complex environment. The buildings range of uses and their management present a set of circumstances which make the approach to fire safety in churches different from any other building type. The physical structure of parish churches specifically, can makes them hard to protect from fire. A summary of the key problems are laid out in table 3.14.

Throughout this building fire performance evaluation primary data is presented. Methodologies for the research studies are detailed in chapter six.

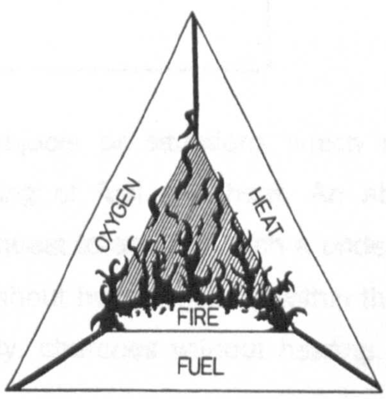
Table 4.1: Analytical framework for the evaluation of fire safety performance in parish churches

Building evaluation		**Building fire performance evaluation**	
Building structure analysis:	• Materials • Methods of construction	Prevention analysis:	• Hazard identification • Possible causes • Likely origins • Ease of ignition • Prevention measures taken
Building use analysis:	• Space utilisation • Property management	Fire growth analysis:	• Fuels and locations • Sequence of growth • Limitation of fire development • Structural stability
Property value analysis:	• Historic value • Functional value • Loss impact value	Fire protection analysis:	• Typical fire measures present • Typical security measures present • Passive protection

4.1.1 Prevention analysis

Fire prevention is the most effective approach to fire safety. If successfully achieved no other fire safety measures are utilised. Fire will only occur when oxygen, heat and fuel are present. These elements form the basic ingredients of fire science and are referred to as the fire triangle. [A full analysis of the principles of fire science is not necessary for an understanding of this thesis. However, some fire terminology is introduced and briefly outlined when appropriate].

Figure 4.1: The fire triangle



The removal of one of the three elements will ensure combustion will not occur. If it is appreciated that the removal of oxygen from habitable buildings is not possible (or at least not realistic), then fire prevention must be achieved through the removal or control of the other two elements of heat and fuel.

4.1.1.1 Hazard identification

The removal or control of heat and fuel can be analysed through the consideration of hazard identification. [As defined in chapter five a hazard is an object (potential fuel) or situation (creator of heat) with the potential to do harm].

For the sake of clarity fire hazards in parish churches are divided into three categories as identified below.

Table 4.2: Fire hazards in parish churches

Fire hazards
1. Energy use • heating plant and equipment • electrical wiring • electrical appliances
2. Natural phenomena • lightning
3. Human activity • repair and maintenance operations • smoking • use of energy active appliances and equipment • use of candles • temporary staging and exhibitions • storage of flammable substances • malicious acts

These hazards are either objects or situations which have the potential to cause combustion through the uniting of fuel and heat. An absolute guarantee of ignition prevention is not possible. A quest to achieve such a undertaking would require that the building is never used. But without human activity within the building, churches cease to function as intended. Similarly, churches without heating, lighting or any other energy generating facilities become unsuitable for use. The threat of fire from the natural phenomenon of lightning will always be present, and can only be protected against by the use of lightning conductor systems. So hazards have to be lived with. But it is the degree of threat that has to be controlled [this is explored further in chapter eight].

Primary data reveals the typical arrangement of heating systems in parish churches. The survey showed 53% of churches have central heating systems, 45% using hot water and 9% using ducted warm air, either fuelled by gas or oil. Of those 53% only 15% use oil and 90% of those churches are rural churches. Gas is being selected to replace oil fuelled boilers in most cases, as it is considered a cleaner option. The survey showed 40% of churches to have boiler rooms located below the ground floor of the building, 24% attached to the church and only 9% with boiler rooms detached from the church. With the increasing use of gas as opposed to oil, more churches are now locating the boilers inside the church. This is leaving many boiler rooms abandoned and standing empty. The second most used heating system is electric radiant heaters fixed to walls [36%]. Again this type of heating is being favoured as it is clean and effective.

Electrical wiring should conform to the Electricity at Work Regulations 1989, and should be checked annually if over five years old in accordance with the Requirements for Electrical Installations issued by the Institution of Electrical Engineers[2]. Wiring in many churches is often over twenty five years old and in need of urgent replacement. Overloaded circuits, and the use of extensive temporary wiring for example in the lighting of lecterns, cribs and Christmas trees can present specific fire hazards.

Electrical appliance equipment typically found in parish churches includes the organ and organ blower, a public announcement system, electric heaters, office equipment such as a photocopying machine and maybe a computer in the office or sacristy and kitchen equipment such as kettles and tea urns as well as electric lighting. The organ is one of the most expensive and sensitive pieces of equipment, however, and also one of the most combustible[3].

The hazard categorisations are not mutually exclusive. Invariably it is the actions of humans that create the situation in which heat and fuel activate to cause fire ignition.
Such hazardous activities specifically noted in parish churches include:

- Unsupervised external groups using the premises.

- Repair and maintenance operations by contractors.
- Amateur repairs to heating and electrical appliances.
- Services which involve the use of large numbers of candles.
- Use of temporary staging and exhibits i.e. nativity scene.
- Storage of flammable substances in the building e.g. cleaning fluids, lawnmower and strimmers with petrol.
- Vandalism and theft from church premises.

4.1.1.2 Causes of fires

Home office fire statistics detail the following causes of fires in places of worship [the methodology for the study is discussed in chapter six].

Table 4.3: Causes of fires in places of worship 1983-1993[UK][4]

Cause	Percentage
Appliance or equipment faults and defects	15%
Unintentional misuse of appliances	7%
Miscellaneous accident and negligence	19%
Malicious or deliberate act (arson)	47%
Other	12%

The largest cause of fire in the assessed period was malicious or deliberate acts of fire raising [47%], which essentially can be interpreted as acts of arson. Other literature considers the figure to be greater. EIG figures[5] show that out of 34 fires in churches causing damage of £50,000 plus between April 1992 and June 1995, 22 [65%] were deliberately started. Perrin[6] argues, however, that the number of fires started deliberately may be higher still as very few fires are recorded as arson because this is a legal term requiring certain levels of proof. Perrin suggests that from his own survey of interviewing fire brigades up to 70% of fires in churches are started deliberately.

It is generally recognised that arson has become a significant threat to churches over the past few decades. The increase of arson in churches manifested itself in the early to mid 1970's. EIG[7] statistics at the time showed that one in four churches could expect to suffer damage from fire, theft or vandalism over a one year period. Today this figure has increased to one in two churches. Perrin[8] supports the theory that up until the mid seventies schools were the focus of the arsonist. Due to the large number of fires security in schools improved. Churches then became the next soft target. The attacks on churches are not showing any decline.

In addition to churches being soft targets for arsonists, complex social issues also contribute to the reasons for arson. A lengthy debate on this topic is not intended in this thesis but some contributory factors deserve a brief description. Firstly, a decline in congregations has led to less involvement and interest by communities in their churches. This, coupled with a general decline in moral standards and religious awareness have led to people not fearing retribution when damaging or stealing from religious buildings. The Theft Act 1968 abolished the offence of sacrilege so stealing from churches was not dealt with so severely.

Secondly, there has been a vast increase in the saleable value of religious furnishings and fittings which has encouraged theft and often arson. And thirdly, there has been an increasing number of politically or religiously motivated attacks on religious shrines, such as the bombing of churches in Northern Ireland and the fire bombing of mosques in England.

Table 4.3 identifies that other causes of fires includes appliance failure and unintentional misuse of appliances generally resulting from well intentioned amateurs using equipment in the church and failing to switch it off on their departure, accounts for 22% of fires. In addition, 19% of fires have been caused by miscellaneous accidents and neglect, which includes fires occurring as a result of human failing, whether it be the careless disposal of smoking materials, leaving flammable materials too close to heat sources or poorly maintained heating or lighting installation. Consequently, the greater the number of people using the building the greater the potential for an incident to occur. It is recognised that historic buildings are particularly vulnerable to fire caused by the action of operatives during the process of repair or refurbishment [see section 2.5.3]. Perrin[9] considers that up to 10% of church fires are caused by contractors.

As a comparison, it is interesting to look at the statistics for causes of fires in places of worship in the USA. The following picture is revealed [as shown in table 4.4].

Most significantly, it can be seen that arson in the USA is not such a significant threat as in the UK. This suggests that American places of worship have greater security than their

Table 4.4: Causes of fires in places of worship 1983-1993 [UK][10] and 1987-1991 [USA][11]

Cause	UK	USA
Appliance or equipment faults and defects	15%	37%
Unintentional misuse of appliances	7%	7%
Miscellaneous accident and negligence	19%	16%
Malicious or deliberate act (arson)	47%	30%
Other	12%	10%

UK counterparts. While fires caused by equipment faults or defects in the USA are significantly larger than in the UK which suggests that maintenance and servicing is being conducted infrequently in American churches.

4.1.1.3 Likely locations of fire origins

Further to the identified hazards and fire causes a review of statistics shows that fires are more likely to start in certain areas of parish churches than others.

Table 4.5: Location of fire origins in places of worship[12]

Location of fire origin		Room in building breakdown	
Room in building'	77%	Place of worship	39%
External fitting	8%	Storeroom	13%
Other external structure	7%	Boiler room	8%
Roof	5%	Kitchen	6%
Roof space	3%	Main hall	4%
		Corridor	3%
		Cloakroom	2%
		Office	2%

Notes: ' Room breakdown shown in right of table

Clearly, it can be firstly seen that over three quarters of fires start inside places of worship rather than from the exterior. Secondly it can be seen that 39% of interior origin fires originate in the main worship area. This area as previously discussed may be segregated into further sub-divided spaces, within which specific areas can be highlighted as being of greatest concern due to the large amounts of combustible material present. Such areas include:

- Concealed spaces: typically these may be roof voids, behind wall panelling or below raised and racked seating areas.
- Storage spaces: where typically cleaning equipment as well as books and other combustible material may be stored.

- Storage spaces: where typically cleaning equipment as well as books and other combustible material may be stored.
- Organ casement: which typically consists of a large void constructed within a timber frames and panelling.
- Vestry/sacristy areas: where typically vestments as well as stationery and office equipment may be located.
- Tower bell chamber: where in addition to a timber bell frame, combustible material in the form of bird nests may be allowed to accumulate.

4.1.1.4 Prevention measures taken

The hazards, causes and likely fire origins have been identified, so now it remains to review what and how fire hazard management occurs in parish churches. While the approach taken by each parish is unique [as discussed in section 3.3.4], a general overview can be gained.

Routine inspections and maintenance form the basis of prevention. Church wardens are required under the Churches Measure 1991 to conduct a visual inspection of the building annually and to implement actions to rectify defects. In addition, the quinquennial survey provides written recommendations for fabric and protection improvements [see section 6.3.2].

In terms of the church warden inspections, there is concern whether effective annual inspections are conducted in all cases. The effectiveness of quinquennial inspections concerning the review of fire safety also seems to be inadequate in some cases. Results from the Leicester Diocese survey showed that 65% of churches considered that the feedback they received in their quinquennial report regarding fire safety was inadequate.

Parishes do receive comprehensive advice from insurers on fire hazard management and recommendations for fire prevention measures implementation. However, the resource commitment for such recommendations is known to be very low. The Leicester Diocese survey showed the following expenditure on fire safety in the last five years [1993-1997] [see table 4.6].

The majority of churches [37%] spent between £100 and £500 which amounts to the cost of an annual service contract for fire extinguishers. Only 10% of churches who spent

Table 4.6: Expenditure on fire safety between 1993-1997 [Leicester Diocese church survey, see section 6.3.1]

Expenditure	Percentage
None	13%
Less than £100	20%
£100 - £500	37%
£500 - £1000	13%
£1000 - £5000	2%
More than £5000	8%

over £1000 can be considered to have made a serious investment in upgrading their fire safety measures.

Good housekeeping prevents the accumulation of rubbish or loose combustible material left in a vulnerable location. Tidiness is an essential part of any fire prevention scheme. It has been observed that housekeeping is generally good in churches with most having a cleaning rota scheme. Most churches are cleaned and tidied at least fortnightly by voluntary helpers [see appendix B4 for the church usage survey profiles].

Security also forms an important element of fire prevention. The high incident rate of vandalism on churches has caused security to receive a lot of attention recently. This includes events such as the national church watch scheme launched in January 1999, EIG security seminar rounds, the creation of the Leicester Diocese risk management group and documents such as *Church Security* written by the Staffordshire Police. The implementation of security measures, however, depends on the views and decisions of the individual PCCs and the wealth of the parish.

The information highlighted and data presented in this prevention analysis is utilised in the development and discussion of the techniques of fire safety intervention, in section 4.1.3.

4.1.2 Fire growth analysis

This analysis starts at the point of established burning and evaluates the ability of a typical parish church to limit fire development in its various spaces by virtue of its structure, layout and content.

Firstly, the principles of combustion and fire growth are outlined. Combustion signals the start of the reaction of fire. The lowest temperature at which combustion of gases and liquids occurs is called the flash point. For gases and flammable liquids this may be at room temperature as their flash point is low. Solid materials need to be heated to well in excess of 100°C [see table 4.7] until they reach their fire point temperature. Solids either melt and then vaporise and burn, or decompose by pyrolysis and give off flammable vapours which will then burn. Therefore it is not the fuel itself which burns, but the vapours given off as the fuel is heated. But once the ignition has begun and the vapours are ignited, these flames will in turn further heat the fuel and increase the rate of production of flammable vapours.

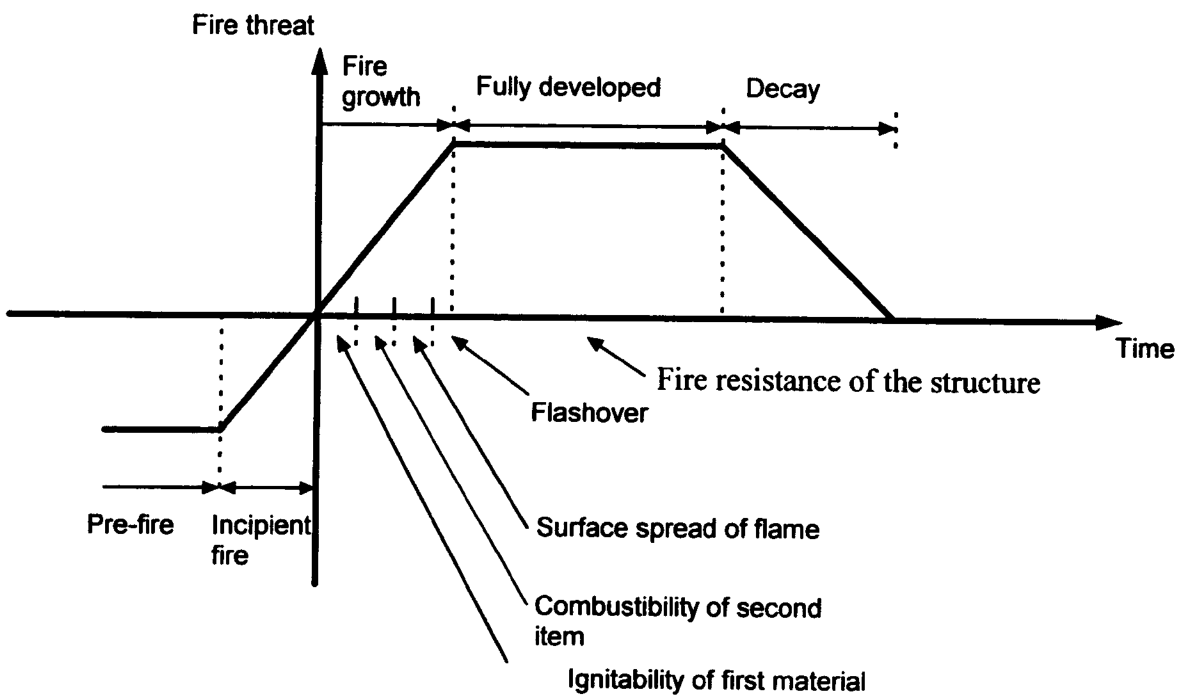
Table 4.7: Ignition temperature of some common solid combustible materials found in parish churches[12]

Material	Ignition temperature °C
Wood	200 - 220
Coal	130
Paper	185
Hay	175
Sawdust	195 - 220

Once ignition has occurred fire grows by the three basic methods of heat transfer: conduction [the movement of heat within solids], convection [the movement of heat within liquids and gases] and radiation [which does not require an intervening medium between the source and receiver].

Fire is unique in its behaviour, due to the random occurrence of factors such as the method and type of construction, surface finishes, positioning and size of combustible materials and the geometry of the enclosure. However, with sufficient fuel and ventilation all fires will pass through a series of stages after ignition. A period of growth is followed by flashover [a point when there is a rapid transition from one dynamically stable condition to another[13]]. A period of stability then exists followed by a period of cooling. The plotting of the temperature of a fire against time gives a fire growth curve [see figure 4.2].

Figure 4.2: Typical fire growth curve and material characteristics[14,15]



An evaluation of the ability of a typical parish church to limit fire development can be addressed by considering factors which influence fire severity. Butcher and Parnell[16] define fire severity as being related to the maximum temperature reached and to the duration of burning. This in turn is dependent on five different factors.

Table 4.8: Factors which influence fire severity[17]

Factors	Conditions for minimum fire severity
1. Amount of fuel	As low as possible
2. Nature of the fuel	Low burning rate and high ignition temperature
3. Arrangement of fuel	In large blocks, minimum area exposed to air. Uniform distribution
4. Size and shape of room or compartment containing the fire	Minimum size, as shallow as possible
5. Area and shape of windows	Minimum area, minimum height

A review of these factors for a typical parish church follows. Factors one to three [see table 4.8] are addressed in section 4.1.2.1 and factors four and five in section 4.1.2.2.

4.1.2.1 Fuels and locations

Chapter three has highlighted the typical structural materials, fixtures and fittings and furniture typically found in parish churches. Here a study undertaken to identify and quantify combustible material in parish churches is detailed.

Fuel load surveys were conducted for the ten sample churches [see chapter six for introduction and methodology]. This involved measuring the surface area of all combustible items in each building. The detailed results are shown in appendix C1, the summary results are presented in table 4.9.

A review of previous studies to quantify combustible loads in buildings revealed that the terminology and approaches to assessment criteria differ, therefore a statement regarding the terminology and criteria used in this study is required.

Firstly, a definition of fuel load and fire load:
'Fuel load' as defined by Stollard[18], is the amount of potential fuel within a building or room, that includes both the building's fabric and contents.

'Fire load' as defined in DD240[19], is the quantity of heat which could be released by complete combustion of all the combustible materials in a volume, including the facings of all bounding surfaces.

It is also necessary to distinguish between fuel loads which form part of the building structure and those that can be considered as building content. Reas[20] uses the following distinction between different fuel loads: fixed load consists of the materials in the construction proper and those which are fixed to it or placed there permanently for use in or decoration of the premises and which could not be removed without causing damage or defacement; the movable load consists of all goods placed in the premises concerned which can be moved about, including those intended for use in and adornment of the premises. This definition has been loosely used in most fire load studies throughout the world. Examples, being studies into fire loads in modern office buildings in America, France, Germany, Netherlands, Belgium and the UK, educational buildings in the Netherlands[21], and hospitals in the Netherlands and the UK[22].

This study uses the following defined criteria:
'Mobile fuel load': all combustible material which can be removed from the building without affecting the shell of the building and/or the structural members.
'Immobile fuel load': all combustible material which forms the shell and/or structure of the building.

4.1.2.2.1 Discussion of the results

The purpose of the fuel load surveys was to provide an indication of the approximate quantity and location of fuel in parish church buildings. There is no known previous fuel load study for English churches. A study of Swiss churches took place between 1967 and 1969[23], however, the basic data sheets are not available, so it is not possible to undertake an analysis of the methodology. In addition, the results are packaged in such a way that a direct comparison between studies is not possible.

From this study key outcomes can be extracted to address the first posed severity factor [see table 4.8]. The results show the churches to have an average mobile fuel load of 27.8 kg/m^2. This figure translates to a fire load of 475MJ/m^2. If this is compared to other occupancies as shown in table 4.9, it can be seen that the mobile fire load for parish churches can be considered to be at a medium level. So in terms of the quantity of fuel present, fire growth would be expected to be promoted and not limited.

Table 4.9: Mobile fire load densities in different occupancies[25]

Occupancy	Average mobile fire load density [MJ/m2]
Libraries	1500
Dwelling	780
Shops	600
Parish churches	**475**
Offices	420
Schools	285
Hospital	230

Turning to the second factor, a review of the nature of the fuel shows approximately 95% of the fuel to be wood [generally pine and oak]. The remaining combustible materials being other cellulose materials [see table 4.10]. Churches generally do not contain large quantities of flammable liquids, foam plastics or other such materials which generate rapid fire spread. Normally the nature of the fuel present can be expected to be predominately cellulose.

An understanding of the arrangement of the fuel within churches is also a critical factor in evaluating expected fire spread. Essentially, the greater the surface area of the fuel exposed, the greater is the potential for rapid fire spread. For example timber in a column or beam is less vulnerable to destruction than the same volume of timber in ornately carved wood panelling. This concept is termed the 'state of division' by the author and the surface profile of the fuel as the 'specific perimeter'. [A suggested approach to gauging vulnerability based on the assessment of the 'specific perimeter' of combustible material is outlined in section 8.6.2].

The fuel load surveys show churches exhibit examples of both fuel which have very small and large surface areas. Generally, dense arrangements of timber exist in immobile structural timber in the form of exposed timber roofs and the bell frame. Such timbers are likely to be protected from complete destruction as the process of charring of the outer surface will occur protecting the inner core of the wood. While the surveyed churches contained many examples of intricate timber including finely carved rood screens, rerodos's and other carved wooden wall panelling. The extent of such intricate surface

Table 4.10: Fuel loads and fire loads for the ten sample parish churches in the Leicester Diocese

Church	Total fuel load [Kg/m^2][i]	Total fire load density [MJ/m^2][ii]	Mobile fuel load [wood] [kg/m^2]	Mobile fuel load [other][iii] [kg/m^2]	Mobile fire load density [MJ/m^2][ii, iv, v]	Immobile fuel load [wood] [Kg/m^2]	Immobile fire load density [MJ/m^2][ii, iv]
All Saints Wigston	**81**	**1378**	27 (34%)	2 (2%)	498	52 (64%)	880
St Andrew Welham	**77**	**1311**	23 (30%)	1 (1%)	418	53 (69%)	893
St John the Bapt. South Croxton	**72**	**1220**	21 (30%)	4 (5%)	424	47 (65%)	796
St Leonard Swithland	**107**	**1830**	26 (28%)	4 (4%)	509	78 (72%)	1321
St Mary Barwell	**87**	**1490**	32 (37%)	3 (3%)	599	52 (60%)	891
St Mary Humberstone	**93**	**1579**	37 (42%)	2 (2%)	666	54 (58%)	913
St Michael Cranoe	**89**	**1511**	28 (34%)	2 (2%)	505	59 (66%)	1006
St Michael Hallaton	**84**	**1424**	21 (27%)	1 (1%)	385	61 (73%)	1039
St Peter Copt Oak	**98**	**1663**	18 (18%)	4 (4%)	380	76 (78%)	1283
St Peter Tilton-on-the-Hill	**79**	**1340**	20 (25%)	2 (3%)	368	57 (72%)	972

Notes: i: The total fuel load is the combined weight [kg/m^2] of all combustible materials

ii: Calculated using the following equation:[25] $$fl = \frac{\sum m_c \times H_c}{A_t}$$ where fl = fire load density [MJ/m^2], m_c = total mass of each combustible material [kg], H_c = the calorific value of each combustible material [MJ/kg] [no account for moisture content taken] and A_t = total internal area [m^2]

iii: Other combustible items: cardboard, carpet, curtain and drapery fabrics, clothes, fibre matting, leather upholstery

iv: Calorific value of wood: 17MJ/kg[26]

v: Calorific values of other combustible items: paper/cardboard: 17MJ/kg, cotton: 18MJ/kg, clothes: 18MJ/kg, cellulose: 17MJ/kg, leather: 19MJ/kg. An overall calorific value of 18MJ/Kg is used[27] finish detail is shown to be largely dependent on the architectural style of the church [this is discussed further in section 8.6]. When reviewing the division between the total immobile and mobile fuel load present, the survey figures show parish churches to have approximately two thirds immobile fuel load to one third mobile fuel load. This figure is contrary to other fire load studies in offices for example, which show a relationship of mobile load (80%) and immobile load (20%)[28]. This illustrates firstly, the extensive quantities of immobile combustible material in churches compared to other buildings and secondly, the high potential for fabric damage as such a large proportion of it is combustible.

The layout of the fuel packages is also an important consideration. In terms of distribution of fuel within spaces of churches [In the fuel load study the term sub-assembly is used to identify spaces within churches. See glossary for a definition, chapter six for the methodology and section 6.6.1 for further discussion], the fuel load survey shows that the largest concentration of fuel is in the nave, although as seen in table 4.11 there is no more than a 17% variation across the surveyed sub-assemblies.

Table 4.11: Fuel concentrations across sample church sub-assemblies [Leicester Diocese Survey]

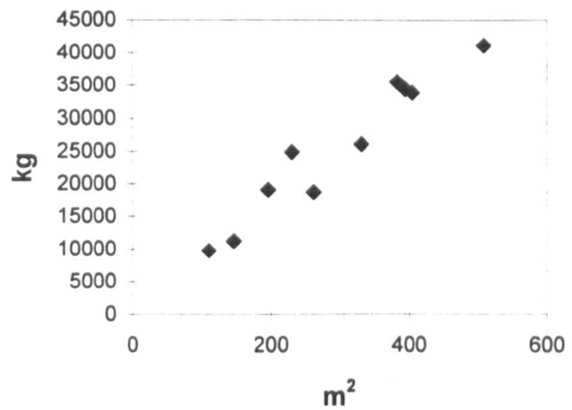
Sub-assemblies[i]	Fuel load [Kg/m^2][ii]
Nave	94.3
Chancel	87.2
South aisle	82.0
North aisle	77.9
South porch	81.8
Tower	81.3

Notes: [i] Sub-assemblies common to more than five churches included
[ii] The average fuel load [immobile and mobile]

The fuel concentrations were in addition tested for consistency between churches. The results show a positive relationship between fuel load and floor area as shown in figure 4.3. An analysis of sub-assemblies further shows that the relationship of fuel load to floor area in chancels and naves are fairly good, but for other sub-assemblies the relationships are less good [see appendix C2]. These results indicate that the distribution of fuel packages in the nave and chancel of churches is fairly standard [for traditionally laid out historic parish churches] and can be predicted, while the space usage of the other areas in churches is individual and a realistic estimation of fuel load is not possible.

The limitations of this study are acknowledged, and detailed in chapter six. However, the results may be used as a guide to estimate the expected fuel load for parish churches overall and the nave and chancel specifically.

Figure 4.3: Sample parish churches: floor area [m^2] versus fuel load [kg]



The location of the individual fuel packages within the sub-assemblies must also be assessed. Progress beyond the item first ignited is by no means guaranteed. Heat transfer by radiation depends on the height and width of the flames and the distance between the flames and the next target surface. Some fires may die naturally as insufficient heat will be generated to progress the fire. In addition, fires are prevented from developing by the application of extinguishing agents. The physical survey of the location of individual fuel packages did not form an aspect of the fuel load surveys. To evaluate the case for churches, statistics in table 4.12 compares the fire spread in places of worship compared to all occupied buildings.

Table 4.12: Fire spread statistics

Fire spread	All occupied buildings[29]	Places of worship[30]
Confined to first item ignited	39%	25%
Confined to room of origin	50%	60%
Confined to building of origin	9%	14%
Spread beyond building of origin	2%	1%

Interestingly the above statistics show that more fires in places of worship spread beyond the item first ignited than the average figure for all occupied buildings [75% in places of worship and 61% in all occupied buildings]. The reasons for this statistics can be suggested. Firstly, lack of early detection and fire suppression in parish churches may be the principal factor. The high incident of malicious fires and fuel packages sitting in close proximity may also aid the fire spread.

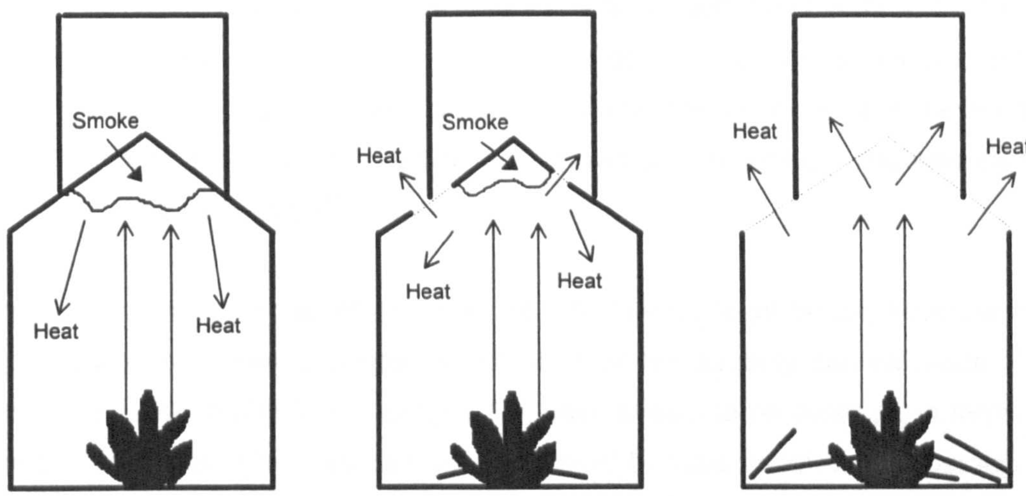
4.1.2.2 Structural stability and compartment geometry

In addressing factors four and five in table 4.8, this section considers the issues of structure, compartment sizes and shapes and ventilation of churches. It was detailed in chapter three that churches are generally constructed from thick masonry walls. Due to this the total destruction of the structure of a church is considered extremely unlikely. This is supported by the EIG's first loss insurance policy approach [see section 2.4.2].

The roofs of churches are combustible and so consideration of how they may act in a fire is necessary. Church roofs may react in three ways [as shown in figure 4.4].

Figure 4.4: Roof collapse options

Sections through a nave and tower



A roof which withstands burnout retains heat and smoke and promotes horizontal fire spread.

A partial roof collapse enables heat and smoke to escape. Horizontal fire spread may occur. Content may also be damaged.

Early roof collapse prevents threat of horizontal fire spread, but content damage is likely to be severe.

Clearly the reactions of the roofs to fire is critical to the outcome of a church fire. Early roof collapse on to irreplaceable fixtures, fittings and content is not desirable, but equally a fire which spreads from a structurally stable roof to another roof is also undesirable. As detailed in table 3.15 [chapter three], fires in church roofs are particularly hard to control which means that effective fire fighting is essential to stop further fire development [see section 4.1.2.2.7 for further discussion].

The height of church roofs influences fire development in two ways. Firstly, the high roofs in churches [the fuel load surveys showed the churches to have an average nave ridge height of 9m] enable a substantial fire to develop before the roof becomes involved. Realistically if flame spread is not propagated by vertically located combustible materials a severe fire is not likely to occur. [see figure 4.5, section 4.1.2.2 and figure 4.2 showing characteristics of flame spread]. If a fire does develop in the main worship area, lack of compartmentation, is likely to result in the loss of the largest enclosure which has been identified to be between 80% and 95% of a church [see chapter nine]. Secondly, high church roofs, can inhibit fire fighting access and fire attack.

In terms of ventilation, the loftiness and spaciousness of churches and their large undivided areas ensure an ample supply of air to fuel a fire. Windows in churches are typically tall and narrow in shape. [the fuel load surveys showed the churches to have an average window surface area of 7%. See appendix C6]. But, not only is the size of the window opening significant their shape can also influence the fire severity. Experimental work has shown that a narrow, tall window will encourage a higher burning rate than a square window of the same area[31].

Now with an appreciation of the influence of the fuel, fuel package layout, structure and geometry of parish churches, a judgement of potential fire severity can be made. The amount of combustible material in churches has been shown to be average. In terms of the arrangement of fuel, churches can be considered to have conditions favourable to restricting fire severity due to the large size of the main enclosure. This consideration is, however, not borne out by the evidence in table 4.12 [that a higher than average number of fires have spread beyond the item first ignited in places of worship allowing slow developing fires to progress]. It is suggested that slow fire detection may be the reason for this statistic. This adds weight to the argument for automatic detection in parish churches. The large main enclosure size, window shape and means of ventilation in churches are more conducive to greater fire severity, once a fire becomes established.

4.1.2.3 Sequence of growth

A series of investigations were conducted into the sequencing of fire growth and fire growth prediction in parish churches to aid the establishment of a clearer destructive potential profile.

4.1.2.3.1 Typical fire growth sequences in parish churches

Firstly, by applying the principles of fire science [applicable to a standard compartment fire] to a parish church, expected sequences can be formulated. Figure 4.5 illustrates the pattern of fire growth of a typical single seated enclosure fire [type 1: normal fire caused by technical failure, human carelessness and natural phenomenal] originating in three different locations in a church.

The illustrations highlight a number of important issues:

- The position of the ceiling is a critical influence in increasing the surface area of the fuel; the time of flashover; the continuation of the fire and the increase of radiant temperature. A fire in the nave with a high roof is therefore unlikely to develop become a fully developed fire.
- Walls also play a critical role in increasing the radiant temperature of combustible material. Typical areas of a church with combustible wall material have been shown to be the organ casement, the altar rerodos, fabric and timber wall hangings and various dividing screens between enclosures.
- Ventilation is a critical factor in fire progression. In churches this is not in short supply, with window and door leakage and large areas of glazing. The flue action of a church tower is likely to considerably increase the speed of fire growth.

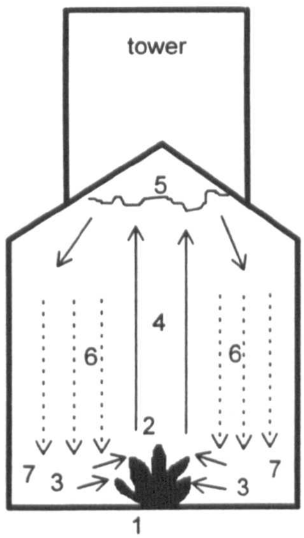
4.1.2.3.2 Estimation of fire growth in parish churches

To provide evidence for the hypothetical sequence framework, research was carried out to gauge the spread and severity of fires within typical parish churches. These exercises were vital for a number of reasons:

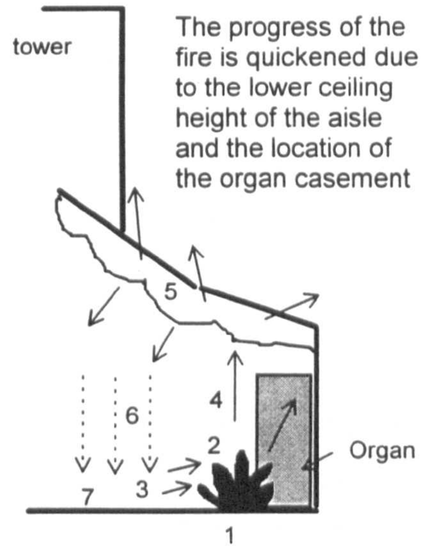
- No known previous work had been conducted.
- It provided a more detailed understanding of the anticipated nature of fire growth in parish churches.

Figure 4.5: Typical fire growths in a parish church

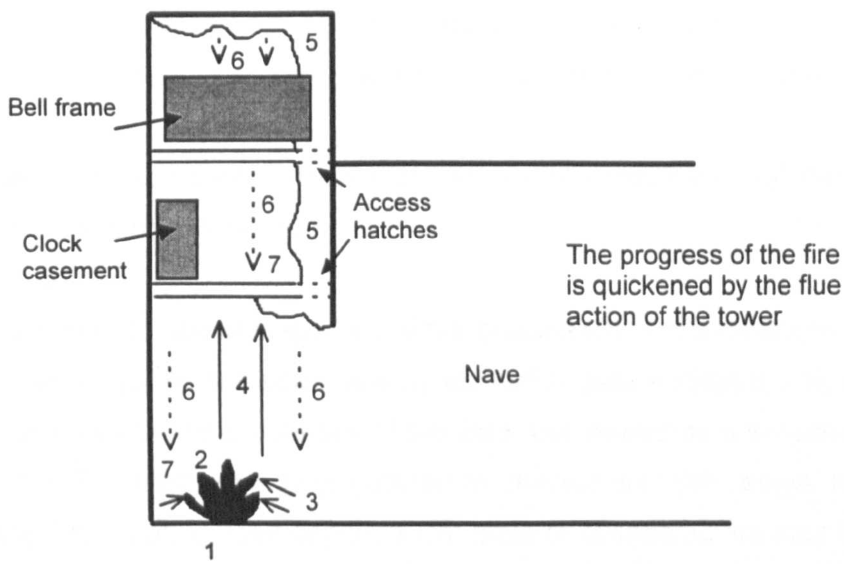
A. Section through a nave



B. Section through a north aisle



C. Section through a typical tower



Key:
1. Ignition
2. Heat release
3. Oxygen drawn in to feed fire
4. Heat and smoke plume rising
5. Smoke layer forms below ceiling and descending
6. Heat radiating down onto surface of content
7. Flashover occurs and a fully developed fire begins

Note: Sketches not to scale

Specifically, the following evidence was sought in the development of the evaluation procedure:

- Examination of typical fire growths in respect to arson fires and those started by other causes.
- An indication of equivalent fire duration and the time for the structural roof collapse.

Three approaches were investigated, the use of past fire incident data, simulations using manual calculations and the use of a fire growth modelling package. An evaluation of the development of computer modelling software packages [see appendix C3] concluded that a computer simulation was not suitable in this case, primarily due to the complex geometry of the enclosures.

4.1.2.3.3 Using past fire incident data

The past incident fires in places of worship provided sufficient information to enable a series of time versus spread relationships to be developed. [The data does not, however, provide enough information to determine what proportion of the enclosure or building is destroyed by fire].

It was decided to focus on fires which occurred in the most common location, place of worship and on large fires [>10m^2]. The fires were further divided into the causes of ignition:

Type 1: technological failure, human carelessness and natural phenomena [normal fire]

Type 2: malicious act of fire raising [abnormal fire]

The data used relies on time estimations made by the fire brigade while in attendance at the fire incident. Further assumptions are also made by the author [see section 6.5.1], so an appreciation has to be given for the crudeness of the data, but viewed as a sensitivity analysis it have credibility. The methodology is detailed in chapter six. The results are displayed in the following three graphs. [see appendix C4: table of abstracted fire data for fires >10m^2].

Figure 4.6: spread versus fire duration for place of worship, all ignition causes

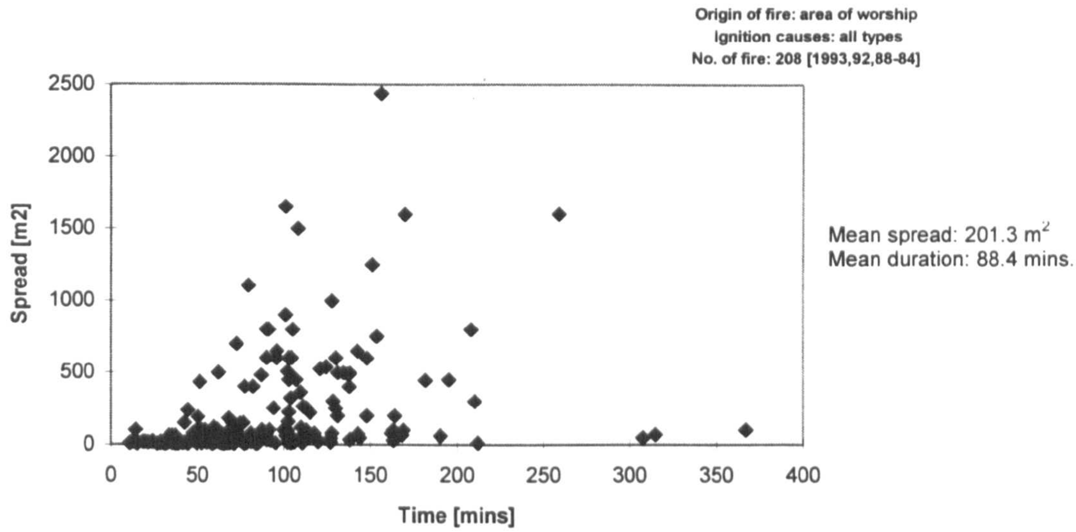


Figure 4.7: spread versus fire duration for place of worship, ignition cause type 1

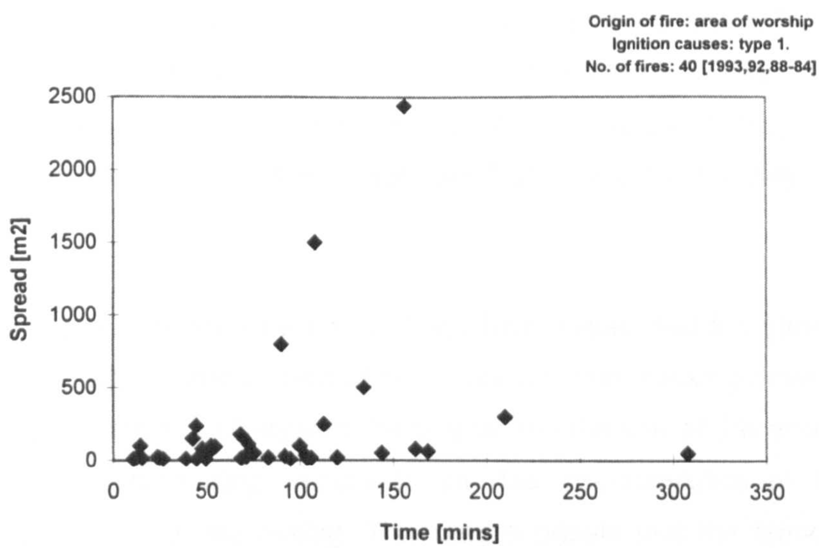
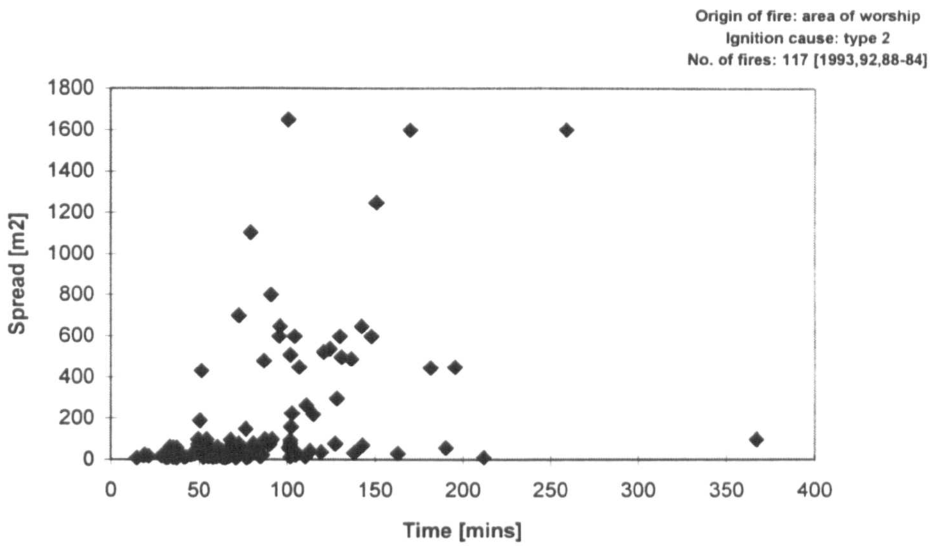


Figure 4.8: spread versus fire duration for place of worship, ignition cause type 2



4.1.2.3.4 Discussion of the results

From figure 4.6 two observations can be made. Firstly, it can be seen that the concentration of fires do not exceed 100m^2 and 150 minutes and consequently the likelihood of a bigger and longer fire can be considered to be low. And secondly, if the mean duration is divided by the mean fire spread a characteristic fire spread rate of 0.4m^2/min can be extrapolated. [This figure suggests a linear rate of increase, but in reality this may not necessarily be correct. Hence it only can be viewed as an approximation, but enables a compared against other building types to be made. See below].

A comparison of the type one and two fires reveals that the general pattern of results is different, with a greater proportion of type two fires causing more extensive damage in a shorter duration. Multi-seated fire origins and the use of fire accelerants are likely to be significant contributing factors to the fire characteristics of those fires caused by malicious acts of fire raising. This data suggests that the fabric and content of parish churches is more vulnerable to damage from type two fires than type one fires.

If the fire load density for churches and the estimated fire spread rate are now brought together, an evaluation of the typical rate of fire growth during the early stages of fire development in parish churches can be considered. In table 4.9 the fuel characteristic of parish churches is shown to be similar to offices [churches 475MJ/m^2, offices 420MJ/m^2]. While the fire growth parameters for individual buildings varies according to the types of material present and the configuration of the enclosure, it may be assumed that that churches are likely to exhibit a fire growth rate similar to offices as their fuel load characteristics are similar. Using the design fire growth tables in DD240[33] [see appendix C5] offices are identified as having a medium fire growth rate. [A 300 second fire will produce a heat release of 1080kW and assuming a heat release of 250kW/m2 a fire of 4m^2 is produced in 300 seconds].

If however, the extrapolated fire spread rate of 0.4m^2/min [figure 4.6] is used, a 4m^2 fire will be reached after 600 seconds which from the design fire growth tables [see appendix C5] is categorised as a slow rate of growth as expected in a picture gallery. It is considered that perhaps in reality, the speed of fire growth in parish churches may actually accelerate from a slow to a medium rate. Lack of early detection [as discussed in section 4.1.3] can enables an extensive period of slow growth to occur. If the fire become established a medium rate of fire growth is then experienced.

4.1.2.3.5 Using manual calculations

To gauge the severity of fires in parish churches, an equation was selected [as shown below] which would provide an approximation of the equivalent fire duration [the equivalent exposure period in a standard furnace]. The duration represents the fire severity of the potential destructive impact [heat punishment] of the burnout of all the available fuel in a room or space with at least one opening[34]. The exercise was applied to the main worship area of each church. An introduction to the sample and the methodology used in this exercise is detailed in chapter six. The results are shown in table 4.13.

$$t = 60\left[\frac{L_f}{\sqrt{A_s A_v}}\right]$$

Where

t	= fire severity (secs)
A_s	= surface area of enclosure interior surfaces, excluding vent area (m^2)
A_v	= vent area (m^2)
L_f	= wood fuel mass (kg)

4.1.2.3.6 Discussion of the results

Clearly, it can be seen that there is a broad range of burnout durations, from 51 minutes at St Andrew, Welham, to 116 minutes at St Leonard, Swithland. While eight out of the ten churches have a close relationship between the level of fuel and fire duration, for two churches that is not the case. St Michael, Cranoe has the fourth largest fuel load [see table 4.10] but only the seventh longest fire duration and conversely St John, South Croxton has the lowest fuel load but the sixth longest fire duration [see appendix C6 for detailed breakdown of fire severity results]. The variance for St Michael can be attributed to the small window area and for St John to the large surface area of the interior.

Table 4.13: Fire severity simulations for the ten sample parish churches

Church	Fire severity: main worship area [min]	Fire severity: main worship area [min] [mobile fuel load only]
All Saints, Wigston	67	24
St Andrew, Welham	51	8
St John, South Croxton	87	25
St Leonard, Swithland	116	51
St Mary, Barwell	86	33
St Mary, Humberstone	112	45
St Michael, Cranoe	73	24
St Michael, Hallaton	96	39
St Peter, Copt Oak	100	33
St Peter, Tilton-on-the-Hill	71	20

Note: As the proportion of other combustible material in the sample churches is small (between 1% and 5%) the total combustible material mass (kg) has been taken as L_f
50% of surface area deducted from floor areas to account for coverage by combustible materials [see appendix C6]
Fire severity measured in minutes

These figures provide an approximate time measure in which detection, communication fire brigade arrival, fire attack, and item retrieval would have to take place, to save the enclosure from total destruction. If the severity figures for the mobile fuel loads only, are focused on, they represent the time by which the content of the enclosure will be consumed. These times range between eight minutes [St Andrew, Welham] and 51 minutes [St Leonard, Swithland]. Estimated fire brigade attendance times for each church are shown in appendix G1. For St Andrew, Welham the estimated fire brigade arrival time is nine minutes [one minute after the burnout of the mobile fuel load]. To avoid a total loss of content in the main worship area of St Andrew's a fire strategy is needed which

Table 4.14: Structural stability of the roofs in the ten sample parish churches

Church	Roofs [main worship area]	Time for roof to fail [mins][i]	Fire severity [mins]	Period of burning after roof collapse [%]
All Saints, Wigston	nave	28	67	58
	chancel	22		67
	south aisle	25		63
	north aisle	25		63
	transept	25		63
	tower. 1.f	35		48
St Andrew, Welham	nave	22	51	57
	chancel	22		57
	mausoleum	14		73
	tower. g.f	25		51
St John, South Croxton	nave	25	87	71
	south aisle	22		75
	chancel	22		75
	tower. g.f	30		66
St Leonard, Swithland	nave	75	116	36
	chancel	22		81
	south aisle	56		52
	tower. g.f	16		86
St Mary, Barwell	nave	28	86	67
	chancel	22		74
	north aisle	28		67
	south aisle	19		78
	transept	22		74
St Mary, Humberstone	nave	26	112	77
	north aisle	22		80
	south aisle	22		80
	chancel	22		80
	tower.g.f	31		72
St Michael, Cranoe	nave	25	73	66
	chancel	25		66
	tower. g.f	25		66
St Michael, Hallaton	nave	22	96	77
	chancel	22		77
	north aisle	25		74
	south aisle	25		74
	tower.g.f	25		74
St Peter, Copt Oak	nave	22	100	78
	chancel	22		78
	transept	22		78
	tower. g.f	62		38
	tower. 1.f	16		84
St Peter, Tilton-on-the-Hill	nave	25	71	65
	chancel	25		65
	north aisle	25		65
	south aisle	25		65

Note: [i] A burning rate of 0.67mm/mins[34] has been used to calculate the roof collapse times [see section 6.5 for a further explanation] utilises first aid fire fighting or the installation of a system of automatic suppression. For the other churches the burnout times exceed the fire brigade arrival times, but this illustrates the need to evaluate the situation of all churches in remote locations as it can not be assumed that fire brigade assistance will be effective. Standard fire brigade arrival times, issued by the Home Office[36] can aid this process.

Further to the consideration of the duration of fire severity it is possible to compare the roof collapse times against the equivalent fire durations to provide an evaluation of the stability of the church structures in a fire. The methodology is detailed in chapter six, the results are shown in table 4.14.

4.1.2.3.7 Discussion of the results

As shown in figure 4.4, it is identified that the roofs may act in three ways. They may withstand a burnout, experience partial collapse or complete collapse during the burnout. It is suggested here, that for churches of high value [grade I], roof collapse before burnout will cause greater damage to structural fabric and content within the enclosure. The period for detection, communication, fire brigade arrival and valuable item retrieval is also reduced. For churches of less value, however, the early roof collapse may be the most desirable course of action, as lateral fire spread is likely to be prevented.

From table 4.14 it can be seen that for all the sample churches, roof collapses occur before burnout. In the cases of St Mary, Humberstone and St Michael, Hallaton a minimum of 72% of the burnout period remains after the collapse of all roofs in the main worship area. Similarly, for the chancel and ground floor of the tower of St Leonard, Swithland, 81% and 86% respectively, of the burnout periods remain. The stability of the roofs in these highlighted cases are poor and consequently are at the greatest risk of fabric and content. This is of most concern for St Michael, Hallaton as it is a grade I listed church and contains fabric and content of considerable value.

The examples here illustrate the need for such calculations to be conducted on individual churches when developing a fire safety strategy. An effective fire fighting strategy can only be established when the stability of the roofs are known and the value of the fabric and content is agreed.

4.1.3 Fire protection analysis

This analysis reviews the typical range of fire precaution measures and passive protection present to limit the extent of fire damage in church buildings.

4.1.3.1 Fire precaution measures

The range of measures considered here includes any equipment located in the building to secure the property, detect a fire, to fight a fire and to guide occupants to safety in the event of a fire. The data presented in table 4.15 are for parish churches of the Leicester Diocese, but it is considered to be typical of churches nationally.

Clearly, it can be observed that the only form of active fire fighting equipment present in the majority of parish churches [91%] is fire extinguishers. [The type and number of fire extinguishers required is shown in appendix G4]

Table 4.15: Existing fire safety and security measures [Leicester Diocese church survey, see section 6.3.1]

Equipment	Percentage
Fire Safety Measures	
Portable fire extinguishers	91%
Hose reels	0%
Water buckets	1%
Fire blankets	10%
Sprinkler systems	0%
Wet/dry risers	2%
Fire detection and alarm system	4%
Exit, safety signs and notices	12%
Lightning conductor	80%
Fire doors	3%
Emergency lighting	1%
Smoke control mechanism	0%
Security Measures	
Security alarm	5%
Surveillance camera	2%
Security lighting	8%
Emergency telephone	9%
Security bars on windows	1%

Auto-suppression systems are those which are activated in the event of a fire without any action by the occupants. The most commonly installed system is sprinkler protection. No church surveyed had any form of auto-suppression system.

Sprinkler protection is a highly developed and reliable, but complex form of fire suppression. It has been in use for over one hundred years, yet has found little favour in providing fire protection in historic buildings in the UK[36]. Within parish churches, an example of a sprinkler system is not known. Past fire incident data in places of worship showed that out of 3233 fires, only five had a sprinkler system in the property. A number of English cathedrals, however, do have sprinkler systems in specific areas of the property [partial installation], Worcester Cathedral is one example.

A strong case for the use of sprinkler systems in parish churches can be made, however. Sprinkler are particularly suitable for use in buildings which are unoccupied for large periods of time, as they can control and in some cases extinguish a detected fire at the incipient stage. For buildings located in rural areas, there may be a considerable delay before the fire brigade arrives. A sprinkler system can control a fire during that delayed fire attack period. As at Duff House in Scotland. Sprinkler systems can also be used to drench specific constructional elements during a fire which increase their degree of fire protection. For example historic doors, which enable the original door to remain and the required fire protection to remain. In addition, the EIG offer a premium rate reduction for a sprinklered building which is a further incentive for parishes to considered the installation of a sprinkler system.

Automatic detection and communication systems in parish churches remain very rare. The Leicester diocese survey showed only 4% of churches have one, and those being churches with adjoining community facilities. The place of worship past fire incident data showed that only 1% of the fires were detected by automatic detection and communication systems [ADCS] which highlights the current, very small contribution made to fire protection in churches of ADCS. A very good case can similarly be presented for the use of such systems, however, particularly optical beam detectors which are effective at protecting large volume interiors[37].

The level of security measures is also shown to be very limited. This is particularly concerning considering the high incidents of church theft and vandalism.

4.1.3.2 Passive fire protection

Parish churches are not suitable buildings to which compartmentation can be applied, as previously stated they consist of largely one undivided space. Further problems can be experienced as boundaries between spaces may not be fire or smoke-tight. This situation may be specifically problematic in churches at the boundaries between levels of the tower through which bell eyelets penetrate and ill-fitting hatch doors provide access.

Fire doors remain very rare in churches although some existing doors have been observed to have intrumescent strips inserted into them in an attempt to improve their fire resistance. Lighting conductor protection, noted to be present on 80% of the churches surveyed is the only form of passive protection widely used.

Compartmentation is being successfully used in large churches and cathedrals to divide undivided roof spaces, however, typically parish churches have open roof spaces.

4.1.4 Techniques of intervention

The building fire performance evaluation has revealed and highlighted a series of issues specific to fire behaviour in parish churches. This evidence can now be used to enable the intervention techniques in the fire sequence to be better targeted specifically for fire in this 'unique occupancy'.

Techniques of intervention form the building blocks of fire safety. Each intervention component must be calculated or organised rationally so that a positive contribution to fire safety is achieved. Table 4.16 identifies the most effective location in the fire development sequence (illustrated in figure 4.2) for each intervention technique. The content of table 4.16 forms the starting point for the development of the fire safety assessment procedure in chapter seven.

4.2 Analysis of Risk

With the building evaluation and building fire performance evaluation of church buildings having been presented, an analysis of the risk can now be discussed. Risk, as defined in chapter five provides an assessment of both the likelihood that harm will occur and a measure of its severity. The former is considered first.

The typical hazards encountered in parish churches has been identified in section 4.1. An estimation of the likelihood of these hazardous events occurring [their probability] can take place in a number of ways:

Table 4.16: Intervention techniques for fires in historic buildings[38]

Stages of fire growth	Stages of fire growth
Stage A: Pre-fire • Housekeeping [waste and flammable item storage] • Retrieval planning, training and practice • Emergency planning and practice • Routine property maintenance • Education and fire awareness for property users and staff • First aid fire fighting training for staff • Environmental monitoring	**Stage B: Incipient fire** • Detection of products of combustion • Communication of detection • Retrieval of local valuable items of content
Stage C: Fire growth • Smoke control • Detection and communication manually [if required] • Warning systems • First aid fire fighting • Emergency lighting activation • Escape routes and access routes for retrieval team • Retrieval of valuable items of content • Passive fire control measures • Fire brigade fire attack	**Stage D: Fully developed fire** • Structural stability • Retrieval of valuable items in adjacent spaces
Stage E: Fire Decay • Stability of the structure • First aid fire fighting • Refuge and rescue	

- Estimation from past fire incident data
- Probability analysis

From the past fire incident data for places of worship a rough estimate of the frequency of various sources of ignition can be made [see section 4.1.1.2]. Insufficient information is available to make estimates as to the likelihood of ignition. Comprehensive statistics are not available for fires in places of worship, which for example do not grow beyond ignition, fires which occur and are never detected or fires which are extinguished by in-house personnel and not attended by the fire brigade. Claim details held by the EIG and other ecclesiastical insurers perhaps represent the most complete picture of the probability of ignition from hazards and hazardous activities, however, it has been found that such details are not readily made available as insurers are not wishing to give their competitors any commercial advantage.

A further limitation is identified by Marchant[39]. A general database on the ignition and burning characteristics of typical combustible contents in historic buildings is not available currently which makes it very hard to produce a realistic estimate of the probability of ignition.

The application of probabilistic risk assessment techniques are covered in DD240[40] and 'The Method'[41]. Such approaches, however, are dependent on the acquisition of reliable data, of which is not available for church buildings.

Due to the constraints discussed, it seems appropriate to adopt the approach taken by the building regulations and insurance companies. That is to make the assumption that fire will eventually occur [100% probability of ignition]. Further to this, it is to be assumed that after ignition, that a steady fire growth will occur, with all of the available fuel in a space available for combustion, as suggested by Marchant[42].

Turning now to the second aspect of risk, a measure of severity, it is possible to identify from the past fire data the general scale of fire severity and to what is at risk from fire in church buildings. Rasbash[43] identifies ten at risk elements in a building. These have been condensed and distributed under the following three headings.

Table 4.17: At risk elements in a building

Life safety • Individuals using or occupying a building • Non-users of the building • Emergency service personnel	**Property protection** • Structural fabric • Immobile fabric content • Mobile items of content
Mission continuity • Loss of functional facility • Loss of economic income facility	

A review of the degree of risk in church buildings to each of the sections above is undertaken.

4.2.1 Life safety

In the UK, past fire incident statistics show that during the period 1983-1993 there were no fatalities in place of worship fires. 97% of fires required no rescue of individuals. Of the 104 casualties, only one fire resulted in multiple casualties [12no.].

Table 4.18: Casualties in UK place of worship fires 1983-1993[44]

	No.
Number of fires	3238
Number of deaths	0
Number of casualties	104

Fire incident statistics in places of worship in North America reflect the UK statistics [see table 4.19]

Table 4.19: Casualties in North American place of worship fires 1987-1991[45]

	No.
Number of fires	1450
Number of deaths	1
Number of casualties	13

Although there has been isolated fire incidents around the world which have results in multiple deaths. The statistics above demonstrate that the risk to life is not high. The principal reasons being:

- Churches stand unoccupied for over 90% of the time and a significant proportion of fires occur when the building is empty.
- The natural layout of churches generally facilitate good evacuation routes and travel distances.

4.2.2 Property protection

As shown in chapter three the cost of fabric loss in the Anglican churches of England and Wales is on average of £5.3 million per year. This figure has been generated by considering the rebuild sum for the destroyed fabric. It is not possible to assess accurately how much lost fabric and content is of a unique nature but an estimation has been made that it is equivalent to the loss of two complete unique historic churches per year[46]. In addition, unique fabric and content which is not destroyed by fire can be damaged by smoke and water to the degree that its quality value can be lost or substantially reduced.

So the fabric and content of historic churches is considered to be vulnerable to fire and consequently of a high risk from fire for the following reasons:

- The exceptional quality of church property, means that any loss of fabric and content is a loss to the cultural heritage of our nation.
- As identified by Marchant[47], the more valuable a building becomes when assessed for the qualities of antiquity and uniqueness, the more vulnerable it becomes to attack by fire.
- Statistics have shown that fire in places of worship are more likely to spread beyond the item first ignited than in other buildings, and fires which pass beyond established burning are virtually impossible to stop as church buildings are essentially one undivided space with ample air supply.
- Evidence has also been presented to show that church buildings generally possess very limited fire safety measures and that coupled with the problems of restricted access, isolated locations, and restricted water supply means that early intervention is unlikely.

4.2.3 Mission continuity

Disruption to the mission continuity generally occurs as a repercussion of the loss of fabric and/or content. In respect to parish churches no known research has been conducted to investigate this specific issue. Observations can be drawn from case studies. If the functional loss of the church is first considered. The experience after the fires at St Peter, Eaton Square, London and St Mary-at-Hill, London were that the fires drew the congregations closer together and engendered a greater sense of belonging[48]. In both cases temporary accommodation was found within close proximity to the ruined churches. Although some fringe members were lost during the temporary location and during the restoration, in the case of St Peter, Eaton Square a growth of 40% membership was experience after the restoration was complete[49]. The successful use of temporary accommodation was also experienced at St Philip, Leicester, where the community hall is still being used for worship three years after the fire. The community hall is considered by some to be more suitable for worship, as it has a more favourable internal environment. In terms of economic loss the example of York Minster can be used to illustrate how after the fire, their visit figures [and revenue] actually went up as people where interested in viewing the ruin and then the restoration of the south transept. This is unlikely to be the case for parish churches.

In the case of this thesis the loss of mission continuity is considered to present a disaster, and the risk of such, equates to that of fabric and content destruction. Although evidence from the case studies shows that in certain circumstances mission loss appears to present more positive than negative outcomes in terms of the spirit and union of church communities as well as economic gain, it is considered not to be the situation in the majority of rural parish churches.

4.3 Summary

In this chapter a clearer appreciation of the behaviour of fire in parish churches and the behaviour of parish churches subject to fire has been presented. Fire hazards exist in parish churches in the form of energy usage, human activity and natural phenomena. Highlighted areas where large amounts of combustible materials can be present include storage spaces, organ casements, vestry and sacristy areas, the tower bell chamber and other concealed spaces. Arson, defined by the Home Offices as a malicious or deliberate act is shown to cause 47% of church fires, although the EIG considered that figure to be even greater. The pattern of arson fires, has been shown to cause more extensive damage in a shorter duration than fires caused by other means.

Fire prevention measures taken in parish churches is shown to be very limited. The only form of active fire fighting equipment present in the majority of churches [91%] is fire extinguishers. This is reflected in the very low investment levels in fire safety measures. The Leicester Diocese survey showed 70% of churches have spent less than £500 on such equipment between 1993-1997. In addition, passive structural protection is not suitable for church buildings as they largely consist of one undivided space. In terms of general housekeeping most churches are considered to be well managed, however, the effectiveness of annual church warden inspections and the feedback from quinquennial inspections regarding fire safety is questioned.

The outcome of the fire growth analysis in parish churches is that the amount of combustible material in churches has been shown to be average. In terms of the arrangement of fuel, churches can be considered to have conditions favourable to restricting fire severity due to the large size of the main enclosure. This consideration is, however, not born out by the evidence in table 4.12 [that a higher than average number of fires have spread beyond the item first ignited in places of worship allowing slow developing fires to progress]. It is suggested that slow fire detection may be the reason for this statistic. The large main enclosure size, window shape, means of ventilation in churches are more conducive to greater fire severity, once a fire becomes established. Calculations conducted, also suggest that an accurate prediction of fire growth in churches involves firstly a period of slow fire growth, followed by a medium rate of fire growth once the fire has become established.

Further calculations have illustrated that fire burnout can occur before the earliest possible fire brigade arrival time and secondly, that roof collapse before fire burnout will cause greater damage to fabric and content, which is of specific concern to buildings containing irreplaceable material. This adds weight to the argument for early detection and automatic suppression in churches.

The outcomes of the building fire performance evaluation are to be used in the careful targeting of the techniques of intervention in the sequence of fire, which in themselves form the starting point for the development of the fire safety assessment procedure.

Finally, it has been argued, utilising the evidence of statistics, that the threat to life from fire in churches is not significant and in itself does not warrant the development of an assessment procedure. The risk to historic property and mission continuity of parish churches from fire is significant. The outcome of this argument is that the fire safety assessment procedure should be developed to evaluate the safety of parish church property exclusively.

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CHAPTER FIVE

FIRE ASSESSMENT METHODS AND TECHNIQUES

5. FIRE ASSESSMENT METHODS AND TECHNIQUES

5.0 Introduction

This chapter presents and reviews methods and techniques of fire assessment. A 'points scheme' approach is identified as being most suitable for the chosen assessment in this thesis. Existing 'points scheme' procedures and key documentation is reviewed and salient aspects which contribute to the development of this unique evaluation procedure are highlighted.

5.1 Fire assessment

With an evaluation of church buildings and a building fire performance analysis now complete, and the demonstration for a fire safety assessment procedure postulated, it is necessary to detail and justify the selection of a suitable fire assessment approach, before the development of the technique is undertaken. This starts with the consideration of what constitutes a fire assessment.

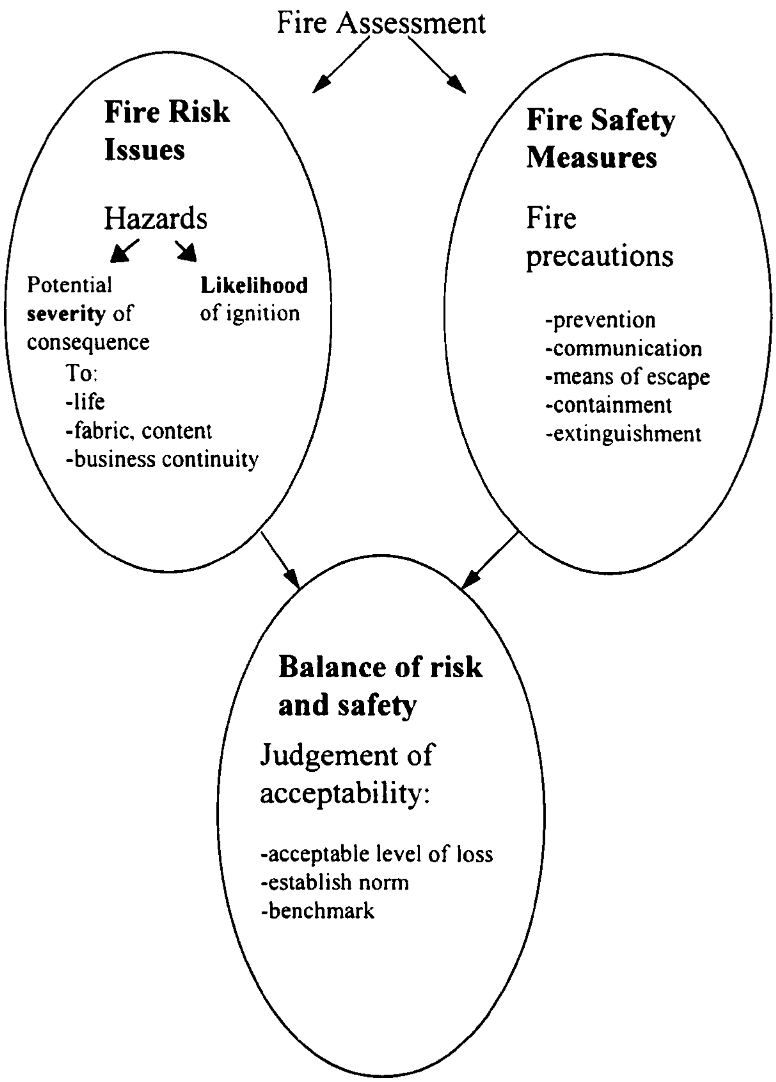
Man has been seeking to provide adequate fire safety in buildings for many centuries. The creation of the fire brigade, the use of non-combustible materials, the use of fire detection, suppression and protection measures are all measures which have been introduced to combat fire loss.

Today fire engineers seek to reduce the level of fire loss to an acceptable level. To do this, the risk of loss and the acceptable level of loss both need to be defined. An array of fire assessment techniques, models and processes have and are being developed to enable systematic approaches to evaluating fire safety to take place. In addition to the multitude of specific assessment models, an assessment of fire safety is now a statutory obligation, required to be conducted in all workplaces in respect to life safety [for which parish churches are included] under the Fire Precautions (Workplace) Regulations 1997 amended 1999[1], [2] [see appendix D1 for further information].

A fire assessment, as identified by Malhotra[3] has two main components: fire hazard assessment and evaluation of fire safety measures [see figure 5.1]. In an ideal system the fire safety measures, by equalling the fire hazard assessment will provide the optimum protection, and by examining different options available the most economical combination can be selected.

Fire assessment consists of the assessment of risk and fire safety and although an evaluation of safety generally follows an evaluation of fire risk it is not always the case as in the example of the hospital evaluation scheme developed by Edinburgh University[4]. But whatever the building or aspect of fire threat to be considered the generic strategy [as shown in figure 5.1] forms a framework for assessment.

Figure 5.1: Generic fire assessment strategy[5]



5.1.1 Definitions of terminology

Before looking in more depth at the process of fire assessment it is necessary to define clearly, the fire engineering terminology used.

'Fire assessment' is the term used to define the overall process of estimating the fire risks and fire safety measures within a building and deducing the degree to which the risks are mitigated, or compensated for by the fire safety measures, with the outcome being measured against an established benchmark. The word 'assessment' can be interchanged with the words 'appraisal' and 'evaluation'.

'Risk assessment' is the term used to define the process of estimating the danger to life, property and mission continuity within a building, by firstly identifying hazards and then estimating the likelihood of harm occurring and a measure of its severity.

'Safety assessment', may be used as an alternate term for fire assessment. It must be understood that risk can be assessed independently of safety but safety cannot be assessed independently of risk.

An appreciation of the difference between hazard and risk is essential to the understanding of fire assessment. Klein[6] defines the two elements as; A hazard is an object or situation with the potential to do harm. A hazard exists or it does not. Its existence is factual, not a matter of interpretation. While a risk is the probability, or chance, or likelihood that a particular hazard will cause harm.

Thus the danger from fire can be defined as the combination of the harm from a hazard and risk. It can be represented by the simple formula:

$D = h_h \times r$

Where

D = danger
h_h = harm from a hazard
r = risk

The severity of the harm from a hazard and the likelihood of the risk occurring can be represented using the following classification scale [table 5.1]. The level of danger is established by multiplying the selected severity by the likelihood. [See section 2.3.2 and appendix A2 for an example of its application].

Table 5.1: Classification scale[7]

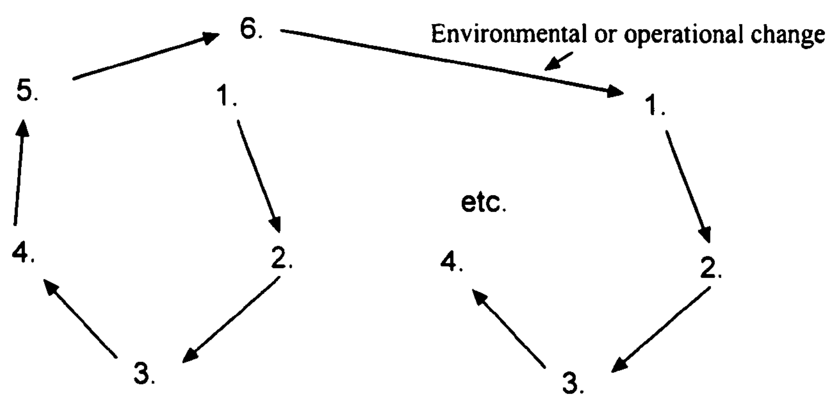
Harm from a hazard [severity]	Value	Risk [likelihood]
Negligible	1	Unlikely
Slight	2	Possible
Moderate	3	Quite possible
Severe	4	Likely
Very severe	5	Very likely

Further to this simple classification scale the magnitude or severity of the danger can be quantified for example by how many people are killed or injured, the area of building fabric destroyed, the amount of content lost, the degree of environmental damage done, or the costs in terms of damage to production time [this is discussed in section 7.5].

5.1.2 The process of fire assessment

To approach any problem effectively, requires a systematic process. Glen and Evans[8] set out the essential elements in the development of an assessment procedure as: 1. Formulate the problem; 2. Collect the relevant information; 3. Devise the solution; 4. Implement the solution; 5. Monitor the performance of the system and 6. Take any necessary corrective action. The authors noted that the process is cyclic and should be carried out continuously and especially after any environmental or operational change as illustrated in figure 5.2.

Figure 5.2: Cyclic systematic approach to an assessment procedure



Key:
1. Formulate the problem
2. Collect the relevant information
3. Devise the solution
4. Implement the solution
5. Monitor the performance of the system
6. Take any necessary corrective action

Further to the generic fire assessment strategy [see figure 5.1], a suggested sequence to the fire assessment of historic buildings is: hazard identification; risk estimation; risk evaluation and risk reduction[9]. Marchant[10] defines three key sections in such an assessment. Firstly the analysis: the estimation of the likelihood of the manifestation of a fire hazard with respect to the functions that are carried out within the building and the environmental control systems that are present. Secondly the synthesis, which includes a survey of all the fire safety documentation on the building, a survey of the physical parts. of the building and a survey of the fire safety systems in the building at the time of the survey. And thirdly the evaluation: the assessment of the adequacy of the fire safety systems in the building in balancing the vulnerability to fire that was identified in the analysis stage. Papaioannou[11] identifies a similar approach to the fire assessment of historic buildings. The assessment consists of four steps: an assessment of the fire hazards; identification of fire safety objectives; estimation of the risk of fire and the preparation of an integrated fire safety package.

5.1.3 Approaches to the assessment of fire

There are essentially two approaches which can be taken to fire assessment, a personal opinion based appraisal and an analytical approach, using subjective or objective judgements.

A personal appraisal approach is simply the opinion formed by an individual after conducting a walk through of the building. A good working knowledge of fire safety systems is important as is a clear understanding of how the building is constructed, and characteristics of the people using the building. Such appraisals normally refer to some authoritative guidance, to act as a desirable state of fire safety. The personal appraisal approach may be suitable in certain situations, but lacks structure and established assessment criteria, and consequently cannot be readily used by another individual to compare the state of other buildings or facilities, and consequently is not considered to be a desirable approach for this thesis.

An analytical approach involves the structured assessment of the danger from fire. The analysis often follows the phenomenological sequence of the development of a fire. Analytical assessment can be divided into three types[12].

Table 5.2: The three analytical approaches to fire assessment[13]

Analytical approaches	Definition
Qualitative approach	An assessment of fire safety based on the personal judgement of an individual
Rationalised systematic approach	The use of qualitative descriptions of events, techniques and processes to which are attached numerical values assigned by a group of experts
Quantitative approach	The study of the phenomenological sequence of the development of a fire and the application of engineering mathematical relationships

Within the context of an analytical approach it is next important to appreciate that there are varying levels of fire assessment undertaken depending on the following factors:

- The level of information available.
- The depth of the problem as perceived by the building owner or professional consultant.
- The level of application: Whole building, system operability, system performance, component performance, sub-component performance[14].

Table 5.3 shows the levels of fire assessment divided into two types. Firstly, those assessments which are considered to be knowledge based and are generally achieved using a qualitative or rationalised systematic approach. In these assessments all systems are assessed superficially and may be only to the level of asking the question does the system exist?[15]. In the quantitatively approached assessments the fundamentals of fire science and engineering are applied.

Table 5.3: Levels of fire assessment

Approaches	Assessments
Qualitative or rationalised systematic approach	• 'Observational survey' • Investigatory survey • Measurement of fire performance
Quantitative approach	• Destructive testing • Modelling of fire behaviour • Dynamics of fire simulations

In addition, consideration must be given to the required knowledge level of the assessor. Table 5.4 shows the suggested level of assessor needed to complete each type of knowledge based assessment. A 'non-expert' for example can be expected to complete only the simplest of observational surveys, while an 'expert' assessor has the required knowledge to complete the full range of assessments. The capacity of the 'semi-expert', however, is not clearly known [this issue is explored in chapter nine].

Table 5.4 : Assessment approaches and levels of assessors knowledge

Approach	Techniques	Non-expert[i]	Semi-expert[ii]	Expert[iii]
Knowledge based approach	Superficial observational survey: Level 0 Level 1	 yes no	 yes yes/no?	 yes yes
	Investigatory survey	no	no	yes
	Measurement of fire performance	no	no	yes

Notes: [i] Non-expert: layperson with not knowledge of building technology, construction methods or fire safety
[ii] Semi-expert: person with a good knowledge of building technology and construction methods but only a limited knowledge of fire safety
[iii] Expert: person with an expert knowledge of building technology a broad appreciation of construction methods and an understanding of fire safety issues and principles

Turning now to consider the most effective assessment approach for the problem in this thesis. The appropriate level of assessment was firstly deliberated upon by addressing the following three questions [table 5.5].

Table 5.5: Selecting an effective assessment approach for parish churches

Questions	Answers
What level of information is available?	Present lack of reliable performance and acceptability data
What is the depth of the problem as perceived by the buildings owner or professional consultant?	No known previous assessment has been conducted so the extent of the problem has not been investigated
What is the required level of application?	The whole building

From the answers above the following decisions were made:

- As the extent of the problems had yet to be investigated the level of assessment initially required was a superficial 'observational survey'. The outcome of which could lead to more specific assessments. Such an assessment can be effectively conducted with the current basic level of performance data available.

- A rationalised systematic approach was chosen in preference to a qualitative one. It is highlighted by Marchant[16] that a wholly qualitative approach has problems connected with equity and consistency.

5.2 Fire assessment techniques

5.2.1 Options and alternatives

Fire safety assessment techniques provide the vehicle to enable fire safety to be measured. There are numerous fire assessment techniques which are suitable for application at different levels of assessment, depending on the approach adopted. A selection of such techniques are outlined in table 5.6.

It has been previously proposed that a rationalised systematic approach was selected as the most suitable assessment approach in this instant. 'Points schemes' provide the technique for fire safety measurement in such an approach. Probability analysis and deterministic models are generally utilised in quantitative assessment approaches.

Table 5.6: A selection of fire assessment techniques

Technique type	Outline description
Points scheme	A numerical process which enables the judgement on the adequacy of fire safety to be undertaken using expert knowledge value weightings
Probability analysis[17]	The process of estimating the likelihood of an unwanted event occurring. Various tools are used to simulate the analysis including: Fault trees: logic diagrams that are used to illustrate the sequence of factors involved in an event Event trees: logic diagrams that illustrate the ways in which a system can fail so that a particular unwanted event occurs Decision trees: structured as a sequence of decision and probability forks, on to which decisions and their effects are placed
Deterministic models[18]	Models based on physical, chemical, thermodynamic and human behavioural relationships, derived from scientific theories and empirical calculations. Examples include mathematical field and zone models [see appendix C3]

5.2.2 'Points schemes'

The term 'points scheme' is used to define the technique utilised in this thesis. Other titles used for this technique include index systems, numerical grading and rating schedules[19].

Essentially a 'points scheme' is a process which enables the judgement on the adequacy of fire safety to be undertaken. Qualitative descriptions of events, techniques and processes are given numerical values assigned by a group of experts in a particular part or combination of parts of fire safety. The output can be summarised in terms of acceptable or not acceptable based on the total number of points scored compared to a stated benchmark. The benchmark enables the assessor to make a decision on the adequacy of fire safety for the whole building or an area of it [this is further explained in section 7.5].

The first forms of 'points schemes' for fire risk evaluation were those developed by insurance companies for calculating insurance tariffs, an example being the Fire Offices Committee [FOC] Tariff System[20]. During the 1960's the chemical industry produced 'points schemes' in the form of the Dow and ICI Schemes for chemical plants[21]. 'Points schemes' were first used for assessing fire risk in specific building types in the 1970's [see section 5.3], although the use of applying a 'wise men' approach [see glossary for definition] has been used for many years, the Building Industry National Council [BINC] Means of Escape from Fire conducted in 1935 is one such example[22].

The 'points schemes' assessment technique is particularly suitable for the problem in this thesis for the following reasons:

1. The inherent flexibility of this approach makes it useful in the appraisal and upgrading proposals in existing buildings.
2. The framework of the technique ensures the results are equable, and that assessments can be both repeatable and reproducible.
3. As the values assigned to the components of fire safety are processed arithmetically, the results can be compared with some norm that represents acceptable safety.
4. Such an assessment offers an immediate appraisal acceptability and a method for the rapid identification of deficiencies.

5. Combined with a knowledge of unit costs for the improvement of components, and of the practicability of improvements, the assessment method is an effective tool in the provision of cost-effective fire safety.

6. The output from 'points schemes' can be a very powerful tool in influencing non-technical decision makers about the importance of fire safety and conforming with fire safety guidance.

5.3 Evaluation of fire assessment 'points scheme' procedures

'Points scheme' assessment procedures can be reviewed with respect to seven characteristics[23]:

Objective: The specific goals to be achieved by the assessment.

Risk factors: The feature or characteristics of the building which are detrimental to fire safety.

Safety factors: The feature or characteristics of the building which contribute towards fire safety.

Balance between risk and safety: The off-setting of the risk factors from the safety factors.

Judgement of acceptability: The residual risk which is considered to be acceptable.

Simplicity of operation: The simplicity of operation from the view of the assessor.

Contribution to cost-effective fire safety: The effectiveness of the procedure to be used as a tool for evaluating cost-effective fire safety.

5.3.1 Review of procedures developed for modern buildings

The most widely used and well documented 'points schemes' are the USA Fire Safety Evaluation System [by Benjamin], the Swiss Gretner Method [by Gretner] and the Edinburgh Hospital Evaluation Scheme [by Marchant][24]. These three schemes are reviewed, along with other recently developed 'points schemes' for 'unique occupancies'.

Benjamin[25]: A fire safety evaluation system for health care facilities [1979]

Objectives: The system was developed to measure the value of alternative packages of fire safety components and enable a comparison to be made with the level of fire safety provided by compliance with acceptable codes. The system was suitable for use on any building defined as a health care facility. The scheme is directed specifically at the attainment of adequate life safety.

Risk factors: Five risk factors are considered.

Safety factors: Thirteen components are identified as making a contribution to fire safety

Balance of risk and safety factors: The risk factors and safety parameters are evaluated separately. The balance is made in four parts, containment, extinguishment, people movement and general safety.

Judgement of acceptability: No judgement is necessary as the system judges the building automatically.

Simplicity of operation: The system is easy to operate but requires some formal briefing and time to devote to the study of the guidance manual.

Contribution to cost-effective fire safety: A number of cost effective retrofit packages have been developed from the assessment procedure.

Gretner[26]: An arithmetical evaluation of fire risk in buildings [1973]

Objectives: This method is concerned principally with the efficient and effective protection of property. The overall objective is to balance the potential hazards with the normal and special fire protection measures so that the residual risk can be regarded as acceptable. The range of applications is very broad and includes apartment blocks, industrial buildings and warehouses.

Risk factors: Seven principal risk factors are combined to give a measure of the potential hazard.

Safety factors: A value for safety is given by the interactions of seventeen safety components which are brought together into three major groups: standard measures, special measures and constructional measures.

Balance of risk and safety factors: The risk and safety factors are initially assessed separately. The ratio of the risk factors and the safety factors then give a measure of the risk level in the building.

Judgement of acceptability: An acceptable residual risk level is given for buildings containing normal risks and normal people. Where the risks are abnormal the acceptable value is reduced by a correction factor.

Simplicity of operation: The scheme is considered to be fairly straightforward to use, but the assessor needs to be knowledgeable about fuel properties, fire science and fire protection systems.

Contribution to cost-effective fire safety: The procedure is considered to have opportunities within its output to enable improvement packages to be quantified.

Marchant[27]: Fire safety evaluation scheme for patient areas within hospital [1982]

Objectives: This scheme assesses the life safety in hospital patient wards.

Risk and Safety factors: No differentiation is made between risk and safety factors as all the factors considered to be important can contribute positive or negative influences on overall fire safety.

Balance of risk and safety factors: Twenty safety components are used to judge a level of deficiency from a perfect safety score.

Judgement of acceptability: Levels of acceptability were generated from the use of a Delphi group and the appraisal of eight real situations.

Simplicity of operation: The scheme is considered to be simple to operate.

Contribution to cost-effective fire safety: Because of the need to evaluate each component, significant deficiencies can be identified and costed readily.

Parks et. al.[28]: Fire risk assessment for telecommunications central offices [1998]

Objective: The system evaluates the risk to life safety and network integrity. The process allows identification of the discrete components and elements that affect fire safety and the assessment is made independently.

Risk and safety factors: No differentiation is made between risk and safety factors as all the factors considered to be important can contribute positive or negative influences on overall fire safety.

Balance of risk and safety factors: The system assesses the level of risk using seventeen risk parameters. The relative weightings for each component is quite different for network integrity than it is for life safety.

Judgement of acceptability: No measure of acceptability is used

Simplicity of operation: The procedure is considered easy to use. An assessor needs only a minimal knowledge of fire protection. A computer programme has been developed to help the assessor perform risk calculations and for recording and encoding survey data.

Contribution to cost-effective fire safety: The computer programme enables the assessment outcome to be instantly coupled with cost data, which allows for the rapid selection of the most cost-effective risk-reduction strategies.

Other unique occupancy 'points schemes' have been developed as PhD research projects. They include the fire safety evaluation of dwellings by Shields[29], an evaluation model for life safety in buildings by Hinks[30] and a fire safety evaluation procedure for schools by Mohd Idris[31]. In addition, a fire evaluation 'points scheme' procedure for evaluating fire safety issues in existing buildings in Hong Kong is currently in development[32].

5.3.2 Review of procedures developed for historic buildings

The application of a 'points scheme' assessment procedures for historic buildings presents specific problems beyond those of modern buildings. A careful analysis of the whole situation of the building must take place and this should include consideration of the historic and aesthetic implications of the property and contents.

There are no known 'unique occupancy' fire assessment procedures for historic property and content. English Heritage[33] have a model for assessing both the risk to life and the risk to generic historic property from fire, flood, storm, theft and vandalism. The model functions on a very simple rapid ranking scale from one to five, but represents the only known assessment model for the potential risk to property.

Only one unique occupancy model for the evaluation of life safety is known. Mohammed[34] produced a system for the evaluation of life safety in museums. The work uses the National Fire Protection Association [NFPA] code 101[35] as an benchmark and the framework developed for the fire safety evaluation of health care facilities[36] as a assessment structure. The system used a professional judgement review to establish the value of safety parameters. The evaluation is made on a fire/smoke zone basis.

In addition, two generic life safety fire risk assessment models for all types of historic buildings exist. Shields et. al.[37] produced a management strategy to establish life safety equivalency for historic buildings. This model presents a structured approach to assess the life safety potential of occupants in historic buildings. The concept of time available versus time required is employed to establish a safety index for the purpose of life safety in the public areas of historic buildings.

English Heritage[38] also have developed a life safety fire risk assessment procedure which is being applied to all English Heritage owned properties in accordance with the Fire Precautions (Workplace) Regulations 1997 amended 1999.

From the review of the fire assessment 'points scheme' procedures a series of key aspects are noted and summarised:

- Each procedure is defined by the objective(s) of the scheme. Life and property assessment are not assessed together, but in parallel.
- Risk and safety factors are handled in two different ways. Either the risk and safety factors are assessed separately and the outcomes balanced, or no differentiation is made as all the factors are considered to contribute positive or negative influences on overall fire safety.
- Risk and safety components are unique for each occupancy and further dependent on the objective of the procedure.
- Each procedure utilises a group of 'experts' to establish weightings for fire safety component contributions, referred to as a Delphi group.
- Each procedure assesses the defined components of risk and safety and has a devised method of establishing the acceptability of the residual risk using an agreed benchmark or norm.
- All procedures are capable of incorporating cost data and thus can be developed into useful tools for priority cost planning.
- All schemes require assessors to have some knowledge of building technology and fire engineering although the extent of the required knowledge does vary throughout the examples.

This review of existing 'point schemes' enables the procedural concepts of an effective scheme to be distilled and utilised. The notes above are used to guide the development of the 'unique occupancy' evaluation procedure in chapters seven and eight.

5.4 Evaluation of key documents

Further to the review of existing 'points schemes', two recently developed generic fire assessment approaches are reviewed and from which further aspects are distilled.

5.4.1 The Building Fire Performance evaluation methodology[39]

The Building Fire Performance Evaluation Method [BFPEM], known as 'The Method' was developed by Professor Robert Fitzgerald at the Worcester Polytechnic Institute. The evaluation method organises the complex systems of fire into a small group of components that enables fire safety performance to be evaluated in a coherent manner and communicated logically.

'The Method' claims to be a generic analytical framework suitable for the analysis of all buildings. It initially evaluates a building's fire performance. This is conducted under five sections: prevention analysis, flame/heat analysis, smoke/gas analysis, people movement analysis and a structural analysis. Risk assessments for life safety, property protection and hazard to firefighters are then conducted. The results of the evaluation methodology provide an illustration of the threats to people, property, the environment and business continuity. It has three levels of applicability: walk through, routine and engineering. The different levels enable the time and resources needed to complete an evaluation, to be tailored to the conditions and objectives of the analysis.

'The Method' uses techniques of probability analysis to structure the complex relationships of the various elements of fire. It uses two approaches to guide thinking, the first is a continuous value network [a motion picture] often called a scenario. The second is a single value network [a few frames from the motion picture] taking a snap shot in time. 'The Method' can be applied to specific building types. It is assumed that past fire data is being input for each building type. The quantification used assigns a probability to the outcome of framework events.

'The Method' is essentially a structured framework for thinking about and communicating what is known about buildings and fire. Because, it is such a broad framework, it does appear to have the potential to become a definite template for fire assessment in the future [for all types of buildings, life and property protection]. The ability of 'The Method' to be used as an integrated or complimentary assessment tool to DD240 is likely.

5.4.2 Fire Safety Engineering in Buildings: Part 1 [DD240] 1997[40]

The draft for development provides a framework for an engineering approach to fire safety in buildings. It is intended that it can be used to show or prove to regulatory authorities or insurance organisations that fire safety requirements can be satisfied. The draft for development may be applied to the design of new buildings and most significantly in the context of this thesis, to the appraisal of existing buildings. The process described in the draft has four main stages: qualitative design review, quantitative analysis, assessment against criteria and reporting and presentation. The draft recognises the essential role of time and sets the process of evaluation against a consistent time framework along which the interaction of parameters are analysed. The evaluation is conducted in a 'stepwise' [see glossary for definition] manner. To facilitate the handling of the large amount of information and data generated by such an approach, it is suggested that an information bus is used. [A concept which uses the analogy of a computer processor to illustrate the flow of information between sub-systems. The information bus clearly shows the input and output element at each 'time step' [see glossary for definition]. The information bus bar is updated to provide a complete snap shot of the situation at any point in time]. The draft acknowledges that the discipline of fire engineering is a relatively young discipline and inevitably some gaps in the understanding of fire still exist. It is up to fire engineers to be aware of the inherent limitations of the application of the draft, as they are professionally accountable for the accuracy and validity of the quantitative analysis. [The draft is not recommended for use by lay practitioners].

The draft recommends a Qualitative Design Review [QDR] as the first stage of a formalised design review and hazard assessment procedure. The significant fire hazards should be identified, the problem simplified and the required extent of quantification established. It is essential to ensure that the calculation techniques are appropriate to the problem under consideration. It is suggested that this stage is conducted by members of a team which may be drawn from the design team, fire engineer(s), representatives from appropriate approval bodies, insurers and operational management. The draft identifies that various aspects of the analysis may be quantified by either a deterministic study, or probabilistic risk assessment, but acknowledges that engineering judgement can play an important part in the QDR.

The quantitative analysis is divided into six steps referred to as sub-systems:

Sub-system 1: initiation and development of fire within the enclosure of origin.

Sub-system 2: spread of smoke and toxic gases within and beyond the enclosure or origin.

Sub-system 3: fire spread beyond the enclosure of origin.

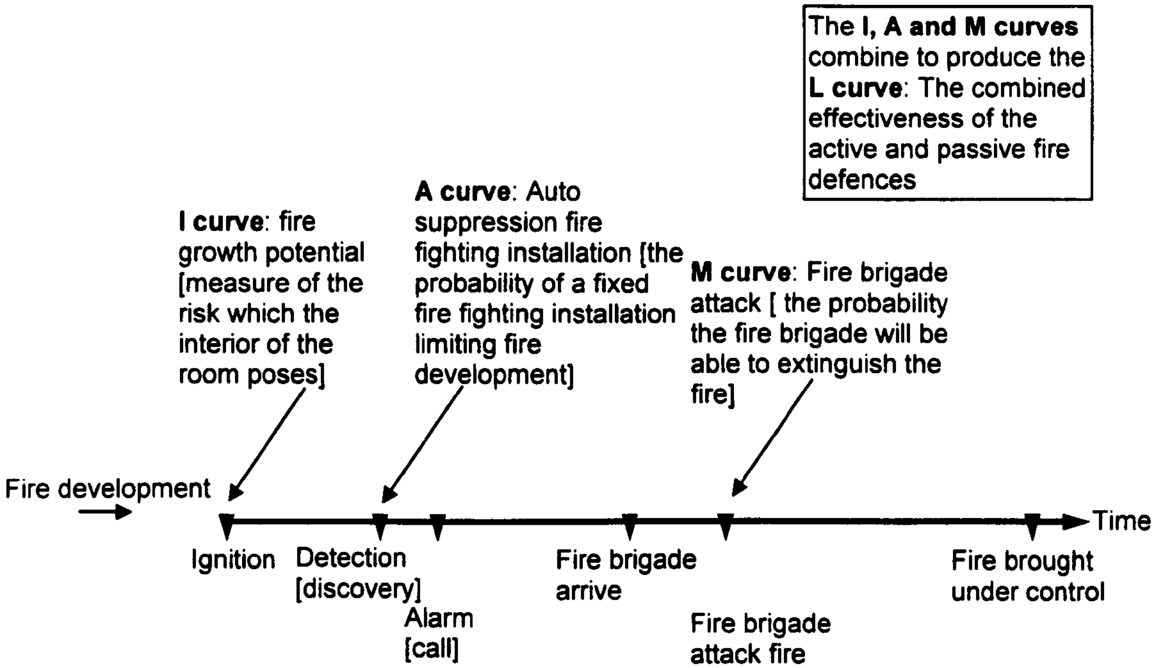
Sub-system 4: detection and activation of fire protection systems.

Sub-system 5: fire service intervention.

Sub-system 6: evacuation from the building.

The common basis for fire safety evaluation in both the above systems is time. To accommodate the complicated interactions between parameters DD240 utilises the concept of a 'time line' [see glossary for definition] as shown in figure 5.3. If the staged assessment detailed in 'The Method' is transposed onto the 'time line' the sequence of evaluation is clearly appreciated [as shown in figure 5.3].

Figure 5.3: Fire safety evaluation 'time line'[41]



As with the review of existing 'points schemes', effective elements of the two reviewed generic fire assessment approaches are utilised in the development of the 'unique occupancy' evaluation procedure. Particular aspects which are used are abstracted below:

From 'The Method':

- The analytical framework for the building fire performance evaluation and the analysis of risk is used as a framework for the initial evaluation of parish churches [see chapters three and four].
- The multiple levels of applicability are mirrored in the strategic framework of the procedure [see chapter seven].
- The single value network [taking a snap shot in time] is used as the approach to guide thinking during the survey work [see chapters seven and eight].

From DD240:

- The 'time line' and the 'time step' approach detailed is used as the structure for the creation of the assessment procedure flow process concept [see chapter seven].

5.5 Summary

A generic fire assessment strategy has been presented and the stepped process of conducting a fire assessment for an historic building is suggested. The assessment starts with the analysis: the estimation of the likelihood of the manifestation of a fire hazard. Followed by the synthesis, which includes a survey of all the fire safety documentation on the building, a survey of the physical parts of the building and a survey of the fire safety systems in the building at the time of the survey. And then the evaluation: the assessment of the adequacy of the fire safety systems in the building balanced against the vulnerability to fire, identified in the analysis stage.

A superficial 'observational survey' is considered to be a suitable initial level of assessment as the extent of the problems have yet to be investigated. The outcome of the assessment may lead to more specific in-depth assessments. A rationalised systematic approach and a 'points scheme' assessment technique is to be utilised.

A 'points scheme' assessment technique is particularly suitable for the inquiry in question as it is flexible in its structure, easy to understand by non-technical decision makers, the assessment is able to be compared with a norm giving immediate appraisal of acceptability and it is really able to be used as a tool in the provision of cost-effective fire safety evaluation.

From a review of existing prominent 'unique occupancy' 'points schemes' and assessment approaches a series of guidelines are taken forward to aid in the development of the 'unique occupancy' fire evaluation procedure.

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CHAPTER SIX

ELEMENTS OF PRELIMINARY SURVEY WORK

6. ELEMENTS OF PRELIMINARY SURVEY WORK

6.0 Introduction

This chapter details the survey work conducted as the groundwork to this thesis. The ten parish churches used as the focus sample are introduced and the methodologies and key results [not already presented in earlier chapters], are expounded.

6.1 Introduction to the survey work

The work detailed in this chapter was undertaken as a precursor to the development of the evaluation procedure. It provides unique first-hand data, the purpose of which was to build up a clearer picture of a typical fire growth sequence for churches so that intervention measures could be more carefully targeted. Although much of the preliminary survey work in itself does not feature in the final evaluation procedure, its inclusion in the thesis is considered valuable as it forms the stepping stones to the final output.

6.1.1. The Diocese of Leicester

The Diocese of Leicester has been used as a test-bed for this research. The diocese stretches from Market Harborough in the south to Loughborough in the north and from Coalville in the west to Uppingham in the east. It covers the entire county of Leicestershire and part of the county of Rutland. The diocese is split into two Archdeaconries, Loughborough and Leicester and thirteen deaneries. There are approximately 310 churches in the diocese, of which approximately 287 are churches constructed before 1914. Of the 43 dioceses in England and Wales the size of Leicester is considered to be average.

In terms of historic churches, it can be seen [table 6.1], that the diocese consists of a larger proportion of listed churches than the national total [90% compared to 75% nationally]. The proportion of Grade I churches is only slightly above the national percentage while the percentage of Grade II* and II churches is significantly higher than the national percentage. [see chapter two for definitions of gradings].

Table 6.1: Statutory listed churches in the Leicester Diocese

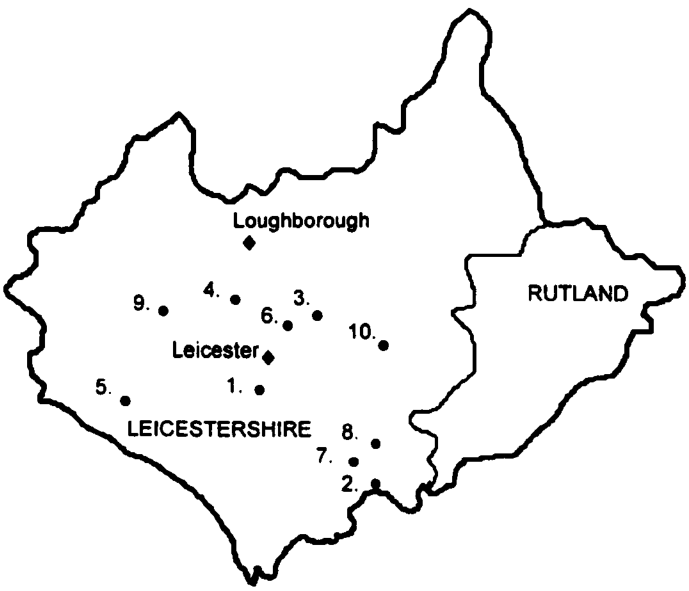
Leicester diocese		Anglican churches of England[1]	
Grade I	18%	Grade I	16%
Grade II*	20%	Grade II* & II[1]	41%
Grade II	52%		
Not listed	10%	Not listed	25%

Note: [1] Distinction below grade II and II* not given

6.1.2 The selected sample

An appropriate sample of churches were randomly selected from the 287 pre-1914 churches, categorised as 'historic churches'. A stratified random sampling technique was applied using church seating capacities to enable a balanced range of church sizes to be represented in the sample. [see figure 6.1, table 6.2 and individual church profiles in appendix E1]

Figure 6.1: Map showing location of churches within the counties of Leicestershire and Rutland



Key:

1. All Saints, Wigston	6. St Mary, Humberstone
2. St Andrews, Welham	7. St Michael, Cranoe
3. St John, South Croxton	8. St Michael, Hallaton
4. St Leonard, Swithland	9. St Peter, Copt Oak
5. St Mary, Barwell	10. St Peter, Tilton-on-the-Hill

Table 6.2: Survey sample

Church	Place	Location	Period of construction	Floor area m^2	Seating capacity [sc]	Stratification
St. Andrew St. Michael	Welham Cranoe	small village small village	1720 & 1868 1800	146 110	60 60	0 - 99 sc.
St. Leonard St. Peter	Swithland Copt Oak	medium village isolated	14C 1837 & 1889	231 196	170 180	100 - 199 sc.
St. John the Baptist St. Mary	South Croxton Humberstone	medium village city suburb	14C & 1925 14C & 1858	262 383	220 280	200 - 299 sc.
St. Michael St. Peter	Hallaton Tilton-on-the-Hill	medium village medium village	14C & 15C 1490 & 1854	405 331	350 350	300 - 399 sc.
All Saints St. Mary	Wigston Barwell	city suburb large village	14C & 19C 14C	508 394	450 450	400 - 499 sc.

6.2 Package 1: Past fire incident statistics

6.2.1 Methodology

Data was retrieved from the Home Office database detailing all fires which occurred in places of worship during an eleven year period [1983-1993]. The data consisted of coded information abstracted from the fire brigade form FDR1 [see appendix E2]. [The fire service have a statutory obligation to complete a FDR1 form after every attendance at a fire location].

The data, however, in its retrieved form, created a number of problems, both in handling the analysis and in interpreting the analysis output. Firstly, in the handling of the data. The data when input into the database from the FDR1 form was often incomplete, the most significant omission being no fire spread dimensions for the years 1991,1990,1989 and 1983.

In terms of the interpretation of the output, it must be aware that the term 'place of worship' [CG], as defined by the Home Office, includes churches [Churches of England, Wales and Scotland and Roman Catholic], mosques and synagogues. But it does not include non-conformist meeting halls. The only approach to abstracting the exact denomination of each building would be to reference the buildings name and address. This information is not readily available from the Home Office database. Written permission from each building's owner or guardian would be required for the addresses to be released. This was not realistic.

So it was initially considered whether such data is a reasonable representation of fires specifically in parish churches. If reference is made to section 3.1.2, Anglican churches are shown to represent approximately 35% of all places of worship [in respect to England and Wales]. If it is considered that non-conformist meeting halls are excluded from the Home Office category CG, parish churches are likely to represent a larger proportion than 35%. It is not realistic, however, to distinguish which non-conformist denominations use meeting halls and those which are classified as a place of worship under the Home Office categorisation.

Even if the 35% figure is used as a very conservative proportion indicator, Anglican parish churches form, by far, the largest single group. Thus it is considered that the data can be used, if interpreted carefully, to give evidence as to the likely cause, pattern and general circumstances of future fires in parish churches. Nevertheless, the limitations of the data must be recognised.

6.2.2 Key results from the past fire incident data

The full results are tabulated in appendix E3. The key summary results are provided below.

The data provides a number of key statistics:

- On average 294 fires occurred each year in places of worship in the UK.
- The majority of fires occurred in the main worship area.
- Malicious or deliberate act [arson] was the largest cause of fires in places of worship.
- The composition of the item first ignited in one quarter of fires was paper or cardboard.

The data confirms several issues:

- The threat to life is not significant.
- Sprinklers are virtually non-existent in churches.
- Detection and alarm systems are virtually non-existent in churches.

The data also reveals some interesting points:

- Three quarters of fires in spread beyond the item first ignited.
- Only 15% of fires spread beyond the room of origin.
- The largest number of call outs occurred between 4.00pm and 8.00pm.
- The majority of fires were discovered between five and 30 minutes after ignition.
- Approximately 30% of fires were extinguished by first-aid fire fighting appliances before the fire service arrived.

6.2.2.1 Conclusions drawn

Clearly this data presents a unique case as to the extent of fires in places of worship, however, caution needs to be taken when drawing definitive conclusions from these statistics in specific reference to parish churches for the reasons discussed previously. An identification of trends and patterns can, however, be gained.

6.3 Package 2: Diocese surveys

Three surveys were undertaken in the Leicester Diocese:

- Fire safety questionnaire
- Quinquennial report sampling
- Spatial layout survey

6.3.1 Fire safety questionnaire

6.3.1.1 Methodology

A questionnaire was sent to all 310 churches in the Leicester Diocese [see appendix E4]. The aim of the survey was to investigate how fire safety is managed in parish churches. The questionnaire sought information on the use and layout of churches, existing fire and security measures, property management issues, details of any fire incidents and also asked for judgments on the historical and architectural merits of fabric and content. The results do not claim to represent the majority of churches nationally, but set the context for the population used in this thesis. It is considered that a larger national review may well reflect many of the results of this survey however.

It is suggested that the 41% usable response represents a balanced sample of churches within the diocese. The sample breakdown [table 6.3] shows the representation in terms of location, size [seating capacity] and historic value.

Table 6.3: Fire safety questionnaire sample breakdown

Location: **Churches of the Leicester Diocese**		**Church questionnaire respondents**	
Archdeaconry of Leicester:	73%	Archdeaconry of Leicester:	42%
Archdeaconry of Loughborough:	27%	Archdeaconry of Loughborough:	58%
Size - seating capacity: **Churches of the Leicester Diocese**		**Church questionnaire respondents**	
0-99	14%	0-100	17%
100-199	35%	100-199	42%
200-299	35%	200-299	23%
300-399	11%	300-399	23%
400-499	5%	400-499	3%

Table 6.3: Fire safety questionnaire sample breakdown [continued]

Historic value: Churches of the Leicester Diocese		Church questionnaire respondents	
Grade I	18%	Grade I	20%
Grade II*	20%	Grade II*	23%
Grade II	52%	Grade II	44%
Not listed	10%	Not listed	11%

6.3.1.2 Results

The tabulated results from the questionnaire are detailed in appendix E5. Relevant aspects of the results have been previously used in chapters three and four to support the thesis.

6.3.1.3 Conclusions drawn

The fire safety questionnaire has provided collaborative evidence as to the level of fire safety currently deployed in parish churches. As reviewed in chapter three, the findings have shown broadly that minimal provision in terms of precaution measures are present in church buildings and the awareness and attitude towards fire safety management is variable, depending on the focus and interests of the personnel responsible. Recent high levels of vandalism, theft and fire in churches have resulted, in there being increased training and awareness programmes available for PCC members to attend. The upgrade of facilities and enhancement of fire safety management awareness amongst parishes is at present still mixed.

6.3.2 Review of quinquennial reports

6.3.2.1 Methodology

A quinquennial inspection is conducted on all churches as required by the Inspection of Church Measures 1955[2]. The survey reviews the condition of the fabric of the church and recommendations are made on repair measures necessary. The survey is carried out by an approved architect although building surveyors can now conduct the surveys if approved by the diocese. It is the responsibility of the individual parish to make suitable arrangements. The diocesan management office sends a reminder to each parish when a quinquennial inspection is due. Most dioceses also provide guidance notes for completing the inspection report.

The results of the fire safety questionnaire, showed that over 50% of PCC's felt that they did not receive effective feedback from the quinquennial reports regarding fire safety. It was considered necessary to investigate this concern further. To achieve this a sample survey of twenty quinquennial reports were studied. The sample was selected by randomly generating twenty numbers between zero and 310. All reports had been conducted in the last five years. The reports were viewed in the Leicester Diocese office.

6.3.2.2 Results

The content of the reports were compared to the guidelines presented in the *Guide for the Quinquennial Inspection of Churches*[3]. The following exclusions were highlighted:

- Fourteen reports did not contained a scale plan of the building.
- Nineteen reports did not use photographs to illustrate fabric damage etc.
- Fourteen reports did not provided a description of the history of the building.
- Six reports did not mention anything about fire safety protection measures being present or make any recommendations for fire safety improvements.

Clearly, the sample review of reports illustrates that some quinquennial reports are failing to fulfill all the guidelines. Discussions with a number of ecclesiastical architects provided a possible explanation for the shortcomings. In the past the content and structure of the quinquennial reports have been rather weak as architects do not spend sufficient time conducting and producing the survey as they feel they can not charge parishes an appropriate fee, as they lack sufficient resources to pay for it. In 1998 a parish would be typically charged £350 for a quinquennial report. The considered real cost for a inspection and report as outlined in the guidelines would be about £700 [four to five hours on the survey and three to four hours on the write up][4]. The appropriate hourly rate is by no means fixed. It seems that architects charge anything from £12 to £120 per hour.

6.3.2.3 Conclusions drawn

It appears that, some quinquennial reports do not cover fire safety at all, while others may not provide sufficiently clear recommendations for improvement.

The quinquennial report seems an effective vehicle for collecting relevant fire safety data and from which an assessment of fire safety could be made. However, the commitment for such a proposal currently resides with the individual PCC's.

6.3.3 Investigation into spatial layouts

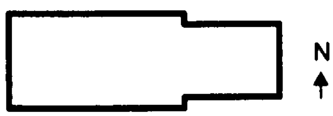
A system was sought for the handling of geometry and interface data in a formalised manner to enable the rapid identification of the layout and interface relationships of individual churches.

While this system framework has not been integrated into the developed evaluation procedure at present, its application is seen to be of necessity when the procedure is advanced to the stage of a computer based expert system assessment.

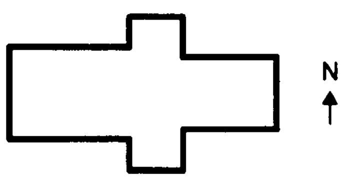
6.3.3.1 Methodology

A study of the evolution of churches [see chapter three] confirms the existence of a series of spaces common to most churches. Each church layout being a hybrid or unique combination of these common spaces with solid or open interfaces. Three classic forms have been identified.

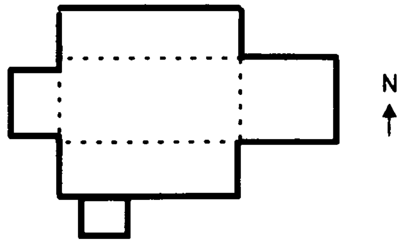
Classic one [C1]: The simplest twelfth century form



Classic two [C2]: The twelfth century cross church with nave, transepts, chancel and central lantern-tower



Classic three [C3]: Typical fifteenth century parish church with nave, chancel, north and south aisle, west tower and south porch.



In addition, a pool of sub-assemblies [see section 6.6.1 for definition and further discussion] have been created which when added to one of the classic forms will produce the individual church layout. The sub-assemblies are divided into three sections: commons, specials and special specials [see appendix E6], depending on how often they are used.

The application of the classic form and the additional sub-assemblies enables each church to receive a code which produces a rapid identification of the layout and interface relationship. This has been termed the 'spatial layout classification'.

Figure 6.2: Example of the application of the 'spatial layout classification'

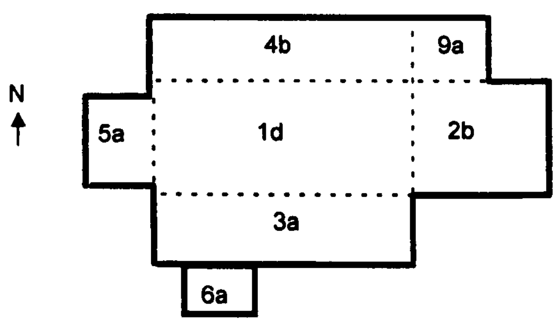
classic form
common sub-assembly code
special sub-assembly code

Classification code: CI/C/S/SS

special, special sub-assembly code

Church: Humberstone

Classification code: C3/4b,2b/9a/0



6.3.3.2 Results

As a pilot trial to test the theory of the classification process a survey of 49 church layouts from the Leicester Diocese was conducted.

The key results included:

- 6no. [12%] fitted the classic layout C3 exactly.
- No church contained a central crossing tower.
- 18no. [37%] consisted of the classic layout C1 plus common sub-assemblies only.
- Of the remaining 25no. churches 12no. [24%] contained some special sub-assemblies and 13no. [29%] contained some special and special specials sub-assemblies.

Although the developed framework is very much at an embryonic stage, the pilot trials have demonstrated firstly, its functionality. They have also highlighted, however, a number of problems. Firstly, in respect to the number of special specials that have to be created to accommodate all possibilities, and secondly the complexity of meshing open and closed interfaces. It is felt that such problems could be resolved at a more detailed development stage.

The limitation of the process also needs to be emphasised. This lies principally in the fact that sub-assembly proportions are not taken into consideration. A layout mesh in a third dimension is also needed.

6.3.3.3 Conclusions drawn

It is considered that the 'spatial layout classification' system outlined, in principle has the potential to act as a system framework for the coordination of spatial data. This embryonic development has demonstrated that potential.

6.4 Package 3: Fuel load survey

As with the fire safety questionnaire the results from the fuel load surveys have been presented and discussed in chapter four in support of the developing thesis. The survey methodology is detailed here.

6.4.1 Methodology

A detailed fuel load survey was conducted for the ten sample churches. This involved the accurate measurement of the surface area of all combustible items in each building. A methodical approach was developed to ensure that all information was gathered using the pre-determined criteria. A set of assumptions and rules were devised for the surveys as shown in appendix E7.

Standard worksheets as shown in appendix E8 were used to gather the survey data in defined sub-assemblies and components. Conversion rates [see appendix E7] were used to translate areas and volumes of measured combustible materials into a unit weight. The fuel load results are calculated in terms of kilograms of all combustible materials per floor area. A calorific value of 17MJ/Kg[5] for wood and 18MJ/kg[6] for all other combustible materials is used to convert the fuel load into a fire load [MJ/m^2] [see notes for table 4.10].

Each survey took between four and six hours to complete and were conducted during the summer of 1997. The results represented a snap shot assessment of the level of fuel present.

6.5 Package 4: Fire duration simulations

Two approaches to fire duration simulations were undertaken: the use of past fire incident data and simulations using manual calculations. The results and approaches used are reviewed in chapter four. Outline methodologies are detailed below.

6.5.1 Methodologies

The past incident fires in places of worship provided sufficient information to enable a series of time versus spread relationships to be developed. Further to the initial analysis of the eleven years of fire incidence data [1983-1993], fire spread and fire duration statistics were abstracted. Seven of the eleven years [1993, 1992, 1988, 1987, 1985 & 1984] contained such statistics for both fire duration and fire spread.

The Home Office data records identify: the time of discovery; time of the first call to the fire brigade; time of arrival of the fire brigade; time the fire is under control and the time the last appliance returned to the station. In addition, an estimation of the time between ignition and discovery is recorded. The options being: discovered at ignition; short time (under five minutes); fairly long time (five to 30 minutes) and very long time (over 30 minutes). For the purpose of this investigation the estimated period from the time of ignition to the time of discovery is added to the initial period to give an overall fire duration period in minutes. The estimated ignition to discovery time has been abstracted using the figures shown in table 6.4.

It was decided to focus on fires which occurred in the most common location, place of worship and on large fires [>10m^2]. The fires were further divided into the causes of ignition:

Type 1: technological failure, human carelessness and natural phenomena [normal fire] and type 2: malicious act of fire raising [abnormal fire]

Table 6.4: Ignition to discovery times

Home Office categorisation	Abstracted time
Discovered at ignition	0 mins.
Short time-under 5 mins	2.5 mins.
Fairly long time-5 to 30 mins	17.5 mins.
Very long time-over 30 mins.	45 mins.

The results, as detailed in chapter four principally identified that the concentration of fires reviewed did not exceed 100m^2 and 150 minutes and consequently the likelihood of a bigger and longer fire can be considered to be low.

Manual calculations where used to gauge the equivalent fire duration of the burnout of all available fuel in the main worship area of the ten sample parish churches and the structural stability of the roofs in a fire. Previous church fires have shown that the thick masonry wall structures of church buildings are not likely to collapse during a fire. These calculations provided an indication of whether the timber roof structures would withstand a complete fuel burnout fire.

Structural collapse was determined by calculating the time for the smallest structural timber roof member, [considered in all case to be the exposed roof rafters] burning at a rate of 0.67mm/min[7], to reach 50% charring, at which point, collapse is assumed. [the value of 0.67mm/min is used as it is a widely accepted estimate for structural species[8]. No allowance has been given for rafters being in tension].

A severity equation was selected which would provide an approximation of the potential destructive impact of the burnout of all available fuel in the largest enclosure. The equation used [as shown in section 4.1.2.2.5] was developed by Law[9]. The equation assumes the enclosure to have at least one opening, [the area of which is greater than that of a typical residential window] and that all the potential energy in the fuel is released in the enclosure.

The results overall showed that the burnout times ranged from 51 to 116 minutes and all the roofs collapse before burnout was reached. The detailed results are given in chapter four.

6.6 Package 5: Fire survey data collection trials and investigations

This package of work consists of trials and investigations into methods of fire survey data collection. Whilst the techniques developed and trialed, are not used in the final evaluation procedure, they form essential preparatory research. In addition, they also represent possible survey approaches suitable to achieve the requirements of the Fire Precautions (Workplace) Regulations 1997 amended 1999[10] [see appendix D1 for further discussions]. The reasons for their exclusion are explained after the review of each technique. The successfully adopted approach is not detailed here, but covered in chapter seven.

The investigations consisted of the trialing of three data collection survey methods developed by the author, the evaluation of the survey approach used by the Ecclesiastical Insurance Group and the evaluation of a hierarchical framework to structure effective surveys.

6.6.1 'Non-expert' data collection survey

At a preliminary stage in the development of the evaluation procedure an examination was undertake to evaluate whether it would be possible for a non-expert to collect suitable spatial and visual data that would enable an expert to conduct a fire safety assessment.

6.6.1.1 Methodology

An attempt was made to develop a survey which would enable a 'non-expert' to collect and record all the data required to carryout a fire assessment of a parish church. The survey procedure [see appendix E9] was developed over a number of drafts, each draft being reviewed by an expert. Every attempt was made to make the survey format as user-friendly as possible. A single trial was conducted as detailed below.

6.6.1.2 Review of the data collection trial survey

Location: St. Peter, Copt Oak

Date: 18 January 1998

Completed by: Church warden

Survey trial methodology:

The church warden was presented with the pilot data collection survey once in the church and was asked to complete it to the best of his ability. He had not been given any prior indication of what the survey involved. During the survey, questions were not allowed to be asked. The respondent was requested to use only the instruction sheet and guide diagrams provided. All queries were detailed by the church warden on the feedback sheet after completing the survey.

Outcomes and issues:

A summary of the key points are presented below.

The respondent took nine minutes to complete the general section of the survey and 45 minutes to complete the survey of the Chancel sub-assembly. The church contained two other sub-assemblies, so a complete church survey is expected to take at least two hours and 24 minutes.

The survey evaluation highlighted two key problem areas: 1. misunderstanding and lack of clarity of the survey sheets; 2. errors in the measurement and identification of data. Problems specifically noted in respect to the former included:

- Moving between sheets was found to be an inconvenience when trying to balance the sheets on a clipboard and walking around.
- Some of the terminology used in the survey sheets was not understood e.g. building footprint.
- The explanation for the use of the transparent protractor was not understood.
- Tracing the layout was found not to be possible if working with a light pencil.

Problems specifically noted in respect to the latter included:

- There was confusion as to what combustible items were to be recorded in linear, square or cubic meters.
- A standard pace can not be used as a reliable estimate. Pace measurement is further obstructed by furniture.
- Measuring vertical heights using the protractor proved to be a problem as pacing was obstructed by furniture.
- Some aspects of fire safety were not recorded as the 'non-expert' did not know where to look e.g. under pew heating and the fire extinguisher placed under the organ seat.

Conclusions:

The trial test provided a clear picture of the many problems associated with the desire for a 'non-expert' to be instructed to collect spatial and fire safety data. The outcome of this trial test indicates that perhaps about 80% of the required information can be expected to be retrieved by a 'non-expert'. Of that 80%, over 90% was inaccurately sized or located [an error of >10%]. This outcome raises questions about the design of the ideal procedure.

The success of this survey largely depends on the attitude of the individual carrying it out. There is a real need to be agile [it is physically demanding] and alert in order to pick up all the relevant information. It is crucial to fully explain to the person doing the survey why it is being done and what is to be achieved.

A structured systematic approach is needed to complete the survey without missing data. This is something that is not likely to come naturally to a 'non-expert' and training would be required before a survey was undertaken. In addition, training would solve some of the problems associated with guidance on how to use the survey sheets.

It is preferable if the survey is undertaken when there is no one else in the building as the respondent needs to concentrate.

The church warden involved in the trial test presented the following feedback: 'most church wardens/vicars would prefer to just call and seek advice from the services of their insurance company rather than get involved with complicated surveys which are very onerous and are not fully understood. It is hard for a 'non-expert' to appreciate the value of the work'.

This survey approach was not pursued further, as the feedback from the trial detailed above, provided clear evidence to indicate that this survey approach was not suitable for the proposed inquiry.

6.6.2 Photographic survey approach

A photographic survey approach was explored as an alternative to the survey technique explained above. The aim of the exercise was to try to reduce the time and complexity of the survey.

6.6.2.1 Methodology

A survey check list and guidance notes were developed [see appendix E10]. The survey required the 'non-expert' to take a photograph of each elevation, internally and externally, noting the measurement of one linear feature in each photograph, so that the photographs could be used to scale off approximate dimensions. In addition, photographs of various other features is required. All photographs are referenced to a key sketch plan of the church. A standard 35mm instamatic camera was to be used. It was envisaged that 35mm disposable instamatic cameras could be sent to be used by the non-expert. At this stage, a single trial was conducted by the author as detailed below.

6.6.2.2 Review of data collection by means of a trial photographic survey

Location: St. Michael, Cranoe

Date: 12 July 1997

Completed by: the author

Issues and problems:

The photographic survey provided a series of photographs from which most spatial and fire safety data could be effectively abstracted. It was found that once the photographs were developed it was essential to number them so their coordination with the key plan could be determined. A full picture of the vertical location of elements could be gained, but not the plan detail however. This proved to be the main problem encountered and the only solution seems to be a physical measure of the plan as part of the photographic survey.

Problems associated with the use of an instamatic camera included:

- For some elevations it was not possible to stand back far enough to get the full elevation in the frame. A wider angle lens than a standard 35mm lens is required. Problems of distortion could then be encountered.
- The camera had to be sometimes angled so the full elevation sat within the frame. This caused errors in measurement estimation.
- The flash on the camera proved too weak for large dimly lit area and some detail could not be seen in the photos.
- For larger churches more than 36 prints would be required.

Conclusions:

Overall, the results of the photographic survey were more positive than the 'non-expert' data collection survey trial. All the required spatial and fire safety data could be established from the photographs apart from the plan spatial detail. It is felt that this survey approach is most effective for small parish churches [maybe up to 300m^2]. But for larger churches the arrangement of photographs may become too complicated.

It must be remembered, however, that this survey was not trialed on a 'non-expert' so the issues of survey sheet clarity and the understanding of guidance notes were not tested.

This method was not pursued as a viable survey option for the fire safety evaluation procedure development, but is seen as having a potential role when the procedure has been developed and tested sufficiently for 'non-experts' to conduct their own church fire safety survey.

6.6.3 Value assessment survey

Considerable thought was put into establishing a suitable approach to determining the value of churches [see chapters two and three for a discussion of the principles and options]. The survey method as shown in appendix E11 provided a self-judgment rating system.

6.6.3.1 Methodology

The survey sheet was developed from the criteria laid out in the statutory listing assessment [see appendix A1] and BS7913[11]. The respondent is required to answer each of the posed questions on a scale of zero to three. The maximum score is 36 and the minimum zero.

6.6.3.2 Review of the value assessment trial surveys

Locations: St. Peter, Copt Oak; St. Mary, Humberstone and St. Michael, Hallaton

Date: 18 July 1997

Completed by: the author

Results:

Table 6.5: Results of the value assessment trial surveys

	St. Peter Copt Oak	St. Mary Humberstone	St. Michael Hallaton
Survey score	12	22	28
Statutory listing	Not listed	grade II	grade I

Issues and problems:

The survey sheet is considered to be straight forward to use. The results above show the output of the assessment to reflect the statutory listing evaluation. The next stage in its development would be to trial the survey on a group of churches, the assessments being undertaken by a number of assessors.

Conclusions:

Essentially the output replicates the statutory listing grades and in so doing provides an indication that the assessment approach works. It must be considered, however, that a comprehensive knowledge of the historic and cultural value of the building is required, which in some cases may require considerable research.

It was decided, that the statutory listing grading would be used as a measure of building worth [see chapter seven for an explanation] during the initial development of the procedure. The value assessment trial, provides a possible framework for a more detailed assessment of building worth which may be necessary if individual churches are to be assessed in more detail.

6.6.4 Survey approach used by the EIG

As part of the investigation into methods of surveying of churches for data, an overview of the survey approach carried out by surveyors of the EIG was undertaken. A blank EIG survey sheet is shown in appendix E12.

Review of an observed insurance survey for a parish church

Location: St. Andrew, Syston, Leicestershire

Date: 17 August 1998

Completed by: Ecclesiastical Insurance Surveyor

Observed by: the author

Extent of survey:

Church surveys are conducted by the Ecclesiastical Insurance Group every ten years or more frequently if requested by the individual church. The survey involves a full spatial survey, the identification of all fabric and content and the recording of fire safety and security measures. The principle aim of the survey is to establish the building and contents valuation. This is divided into the following sections:

- Valuation of the building fabric including fixed fixtures and fittings
- Valuation of portable items
- Valuation of all other items e.g. altar rail
- Valuation of the organ
- Valuation of the stained glass

Although the range of fire safety and security measures present are noted no evaluation of the level of safety is undertaken. The insurers, in response to the measures noted, offer standard advice on fire and security improvements as well as offering discounts in premiums if measures are installed.

Technique:

Horizontal measurements are all taken with a surveyors rod. Vertical measurements are made by component measurement and gauging. The surveyor is expected to work within +/- 5%. All information is recorded on a standard survey form as shown in appendix E12. The coded data is then transferred to a computer programme which calculates the building valuation and restoration costs.

Duration:

A typical parish church survey takes in the region of five hours. A casual interview with the church warden is first undertaken to determine issues of building management such as whether a contract for fire extinguisher servicing is in place. This is then followed by the practical survey which takes about four hours.

Conclusions:

The observation of an insurance survey has confirmed, firstly the approach taken and secondly, the purpose of the survey. The observation has also identified that some information required for an evaluation of fire safety is not included in an insurance survey. For example, an evaluation of fuel loads and the size of fire enclosures. This clearly confirms the proposed evaluation procedure is unique.

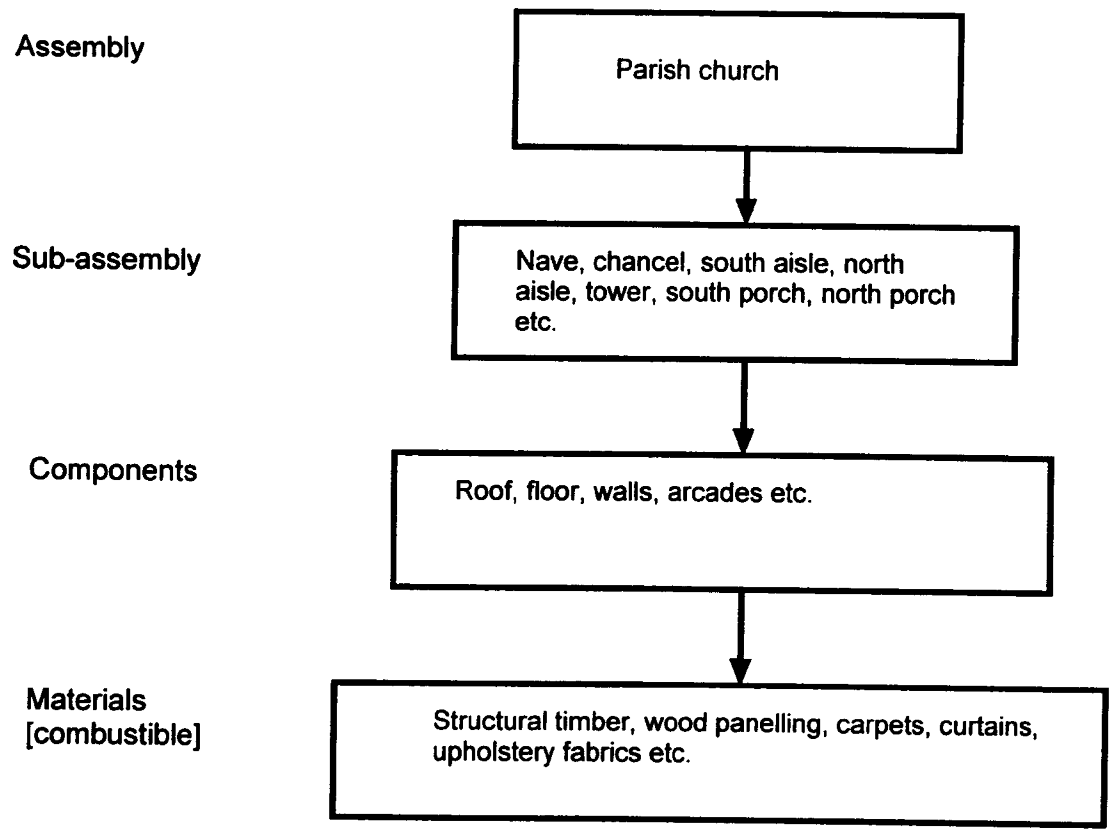
6.6.4 The use of a hierarchical framework

The principles behind buildability was explored as a means of structuring the survey breakdown of the property as shown in figure 6.3.

A hierarchical framework was developed for the survey breakdown of the property. The framework is termed 'artifact dissection' [see glossary for definition] and presents a structure within which various levels of survey details can be objectively assessed. It is argued that the framework provides a robust paradigm which can achieve repeatable results. The concept of the hierarchy has been taken from a simplified buildability philosophy. The concept of buildability has not been applied to the analysis of existing buildings outside of the production process. This approach represents an innovative use of buildability as an analysis tool. The framework represents the interfacing attribute of Ferguson's[12] m/c/sa buildability model but in reverse. Ferguson's model[13] uses the conversion process which turns materials into components, components into sub-assemblies and sub-assemblies into the final assembly [the artifact]. For the purpose of this work, it was considered that the analysis should commence at the largest scale first and then work down to the smallest scale when required. It has been proposed that at the fourth level of detail [the material level] it can be replaced with a number of different detailed elements depending on what survey detail is being analysed. It is proposed that the fuel load and fire load is particularly appropriate for the structured framework.

This hierarchy has been created as a means of handling the complicated survey of

Figure 6.3: Hierarchical framework for 'artifact dissection'



of building details. It is a framework tool and nothing more. In the context of this research work, only the component, sub-assembly, assembly interface sub-division has been used to identify spaces within churches [see appendices C1, C2, E6, E8, E9 & E10]. The reverse buildability concept has the potential to be developed further.

6.7 Summary

This chapter has detailed the elements of preliminary survey work which form a series of fundamental stepping stones towards the final output. As has been stated, most of the work reviewed, is very much at an embryonic stage and is set to be developed further outside the scope of this thesis. However, for the completeness of the description of the research process and in the search for a system of analysis that could be used as the basis of a procedure for fire assessment, each section has been concluded separately, showing clearly the level of development and its relationship to the present inquiry.

This chapter completes the description of the ground work for the thesis. In the following chapters the development of the evaluation procedure is described.

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CHAPTER SEVEN

DEVELOPMENT OF THE EVALUATION PROCEDURE

7. DEVELOPMENT OF THE EVALUATION PROCEDURE

7.0 Introduction

This chapter presents a description of the evaluation procedure and sets it in an overall framework. The stages of its creation are identified, the problems of its evolution are discussed as is the intended method of its operation. The use of a hierarchical process of analysis and a norm assessment standard are also introduced. This chapter guides the reader through the operational mechanics of the evaluation procedure.

7.1 A review of the evidence

7.1.1 Need, understanding and justification

Evidence in chapters two to four has supported the need for a fire assessment tool to aid in the fire safety management of parish churches. This chapter starts by outlining the outcomes of a primary study to identify the required focus of the evaluation procedure. This study addresses four key questions, the answers from which, essentially formed a design brief for the procedures development.

- What is the procedure intended to assess?
- What is the intended outcome of the procedure?
- Who will be the intended users of the procedure?
- At what level of detail is the enquiry to be conducted?

In this chapter the answers to the five questions are presented in retrospect.

What is the procedure intended to assess?

As detailed in chapter four, it has been established that assessment of fire safety in respect to property protection specifically is necessary. An assessment of business continuity is considered to be suitably covered in a property assessment. An assessment of life safety is not needed, although some issues relating to life safety will be considered, such as means of access and egress.

What is the intended outcome of the procedure?

In chapter three, it has been clearly identified that some parish churches possess unique irreplaceable fabric and content. It has also been identified that very little revenue is available to dioceses and parishes to protect valuable fabric and contents. With such scarce resources there exists a need for an evaluation procedure which can produce a structured, cost effective mechanism for the assessment of the level of fire safety set against an evaluation of the value of church property. A procedure which prioritises the loss minimisation of valuable fabric and contents. Ideally, a procedure is required which produces a rating at a whole building level, from which the scores can be used to identify the fire safety priorities in a group of churches or throughout a complete church diocese. And at a single building basis, so that analysis can be made at both an individual space level within a building and at an individual fire safety system level.

Who will be the users of the procedure?

There is likely to be a difference between the potential users of the procedure and the potential users of the output from the procedure. While developing the procedure, it is intended to initially use 'expert' assessors. As the procedure is developed 'semi-expert' and 'non-expert' assessors may be introduced. Early research identified four potential users of the output from the procedure:

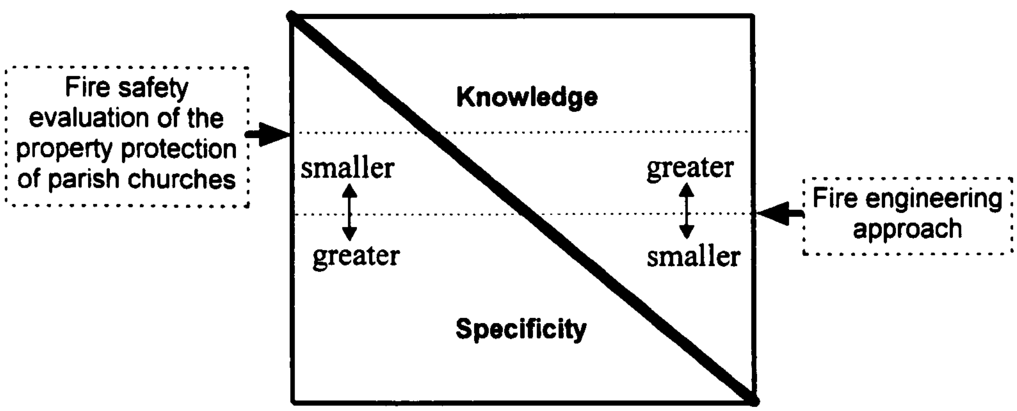
- The diocesan management, responsible for managing the diocese on behalf of the church commissioners, would benefit from a mechanism which could rank all the churches in their diocese in respect to their combined potential fire damage and property value. This would aid decision makers in the allocation of scarce resources.
- The PCCs, the guardians of individual churches, would benefit from a fire safety assessment at an individual space level within a building and at also at an individual fire safety system level. The output could guide PCCs in protecting those areas identified as being most at risk.
- The fire engineer or insurance surveyor could utilise the elemental results to develop fire safety upgrade strategies and to calculate fire safety upgrade options.
- The procedure could also be undertaken during building or refurbishment work, the output of which could be used by building contractors or other contractors working on the property to assess the additional fire threat potential created by the presence of building work. The outcome of the assessment could become part of the health and safety plan as required under the Construction Design and Management Regulations 1994[1].

In addition, the evaluation procedure may be considered a suitable framework for conducting a fire risk assessment as required by the Fire Precautions (Workplace) Regulations 1997 amended 1999.

At what level of detail is the enquiry to be conducted?

As discussed in chapter five, no known evaluation procedure for the property protection of parish churches has been developed so the extent of the problem in individual churches has not been investigated. This procedure is to be developed as an initial 'observational survey', in which all systems are assessed superficially. The outcome of which may lead to more detailed assessments. If the problem is applied to the illustration shown below, the level of this enquiry is estimated to lie closer to a full knowledge based enquiry, than a specific quantifiable problem. As a comparison, the application of a typical fire engineering approach [the guided approach detailed in DD240[2]] is considered to sit half way between the two extremes.

Figure 7.1: Addressing the enquiry: knowledge versus specificity[3]



7.1.2 A MOGSA analysis

In turn, it was deemed beneficial to package the procedure into a hierarchical problem solving framework to guide the enquiry. A MOGSA approach, suggested by Moore and Hague[4] is used.

Mission: To develop an evaluation procedure which will provide a relative assessment of the fire safety for the property protection of historic churches.

Objectives: To assess the level of fire safety in relation to the following:

- Property protection
  - Structural fabric
  - Immobile fabric content
  - Mobile items of content
- Mission continuity
  - Loss of functional facility
  - Loss of economic income facility

Goals: To identify, evaluate, and balance the contribution of fire safety components to fire safety and fire vulnerability with respect to the above objectives.

Strategy: To develop and apply [in a prototype form] an evaluation procedure, using a rationalised systematic approach, capable of being conducted initially by expert assessors.

Actions:

- Gain a clear understanding of the function, usage and management of parish churches
- Establish an appreciation of the building fire performance of parish churches
- Evaluate the degree of risk from fire in parish churches
- Select a suitable fire assessment approach
- Select a suitable fire assessment technique
- Establish a benchmark against which assessment can be made
- Develop an evaluation procedure using a hierarchical analysis approach
- Establish a method of weighting validation for the resultant procedure
- Test and apply the resultant procedure

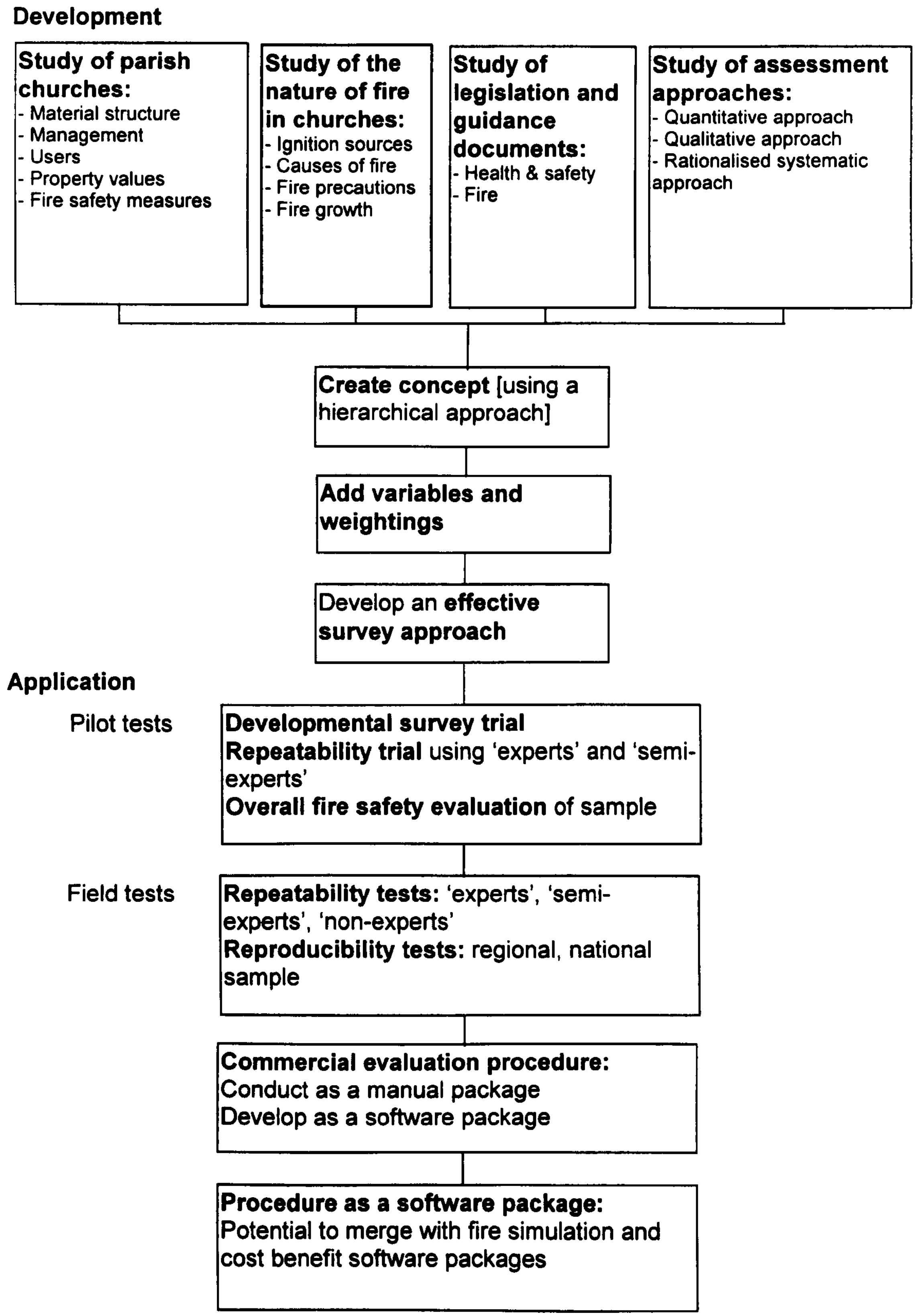
7.2 Creation of the evaluation procedure

The structure of the assessment procedure from concept to working commercial model is firstly explained. Its evolution is laid out in a creation framework.

7.2.1 The overall framework

The creation framework for the evaluation procedure consists of two distinct sections, the development and the application elements [see figure 7.2]. This thesis covers the

Figure 7.2: Creation framework: Evaluation procedure development and application



development stage and takes forward a prototype evaluation procedure to the pilot test application stage. [If the creation framework was laid on a hypothetical scale of one to 100, then perhaps the work undertaken in this research project equates to one to 30]. An overview of the complete creation of the assessment procedure is provided here to illustrate its context and potential.

7.2.2 Overview of the evaluation procedure

Figure 7.2 illustrates the complete creation framework as previously explained. Before the detailed evolution of the procedure is tackled, a concise explanation of the operation of the assessment procedure is presented.

The fire safety evaluation procedure for the property protection of parish churches [to be referred to as Fire [SEPC]] is designed to assess the overall fire safety rating [OFSR] of individual properties. The procedure balances the vulnerability of church contents and fabric to fire against the fire safety of the property [see section 7.3.5 for a detailed explanation].

The vulnerability of church buildings is assessed by evaluating the loss impact of the property and the potential extent of the loss from fire [see section 7.3.5], while the procedure generates a series of elemental component scores [see chapter eight] which are brought together to produce a fire safety assessment score for individual churches. This score, is in turn, set against an agreed benchmark referred to as a 'collated norm' [see section 7.5].

The flow diagrams in figures 7.3 and 7.4 illustrate two options for the utilisation of the overall fire safety rating output. In option one, the OFSR is compared to an 'acceptable level' of fire safety [see section 9.4.4]. For those churches which do not achieve the 'acceptable level' the procedure enables a post-assessment breakdown to be conducted to highlight specific deficient fire safety components. The procedure also has the facility to make direct links between improvements in the fire safety assessment score and the actual cost of making fire safety improvements. A cost-effective strategy can then be deployed to resolve the deficiencies [see section 9.5.2]. Option two shows an alternative approach, where by the procedure ranks the OFSR for individual churches [within a group of churches or maybe an entire diocese]. From the priority ranking, fire safety deficient churches are highlighted and resources are allocated to those

Figure 7.3: Evaluation procedure flow diagram: option 1

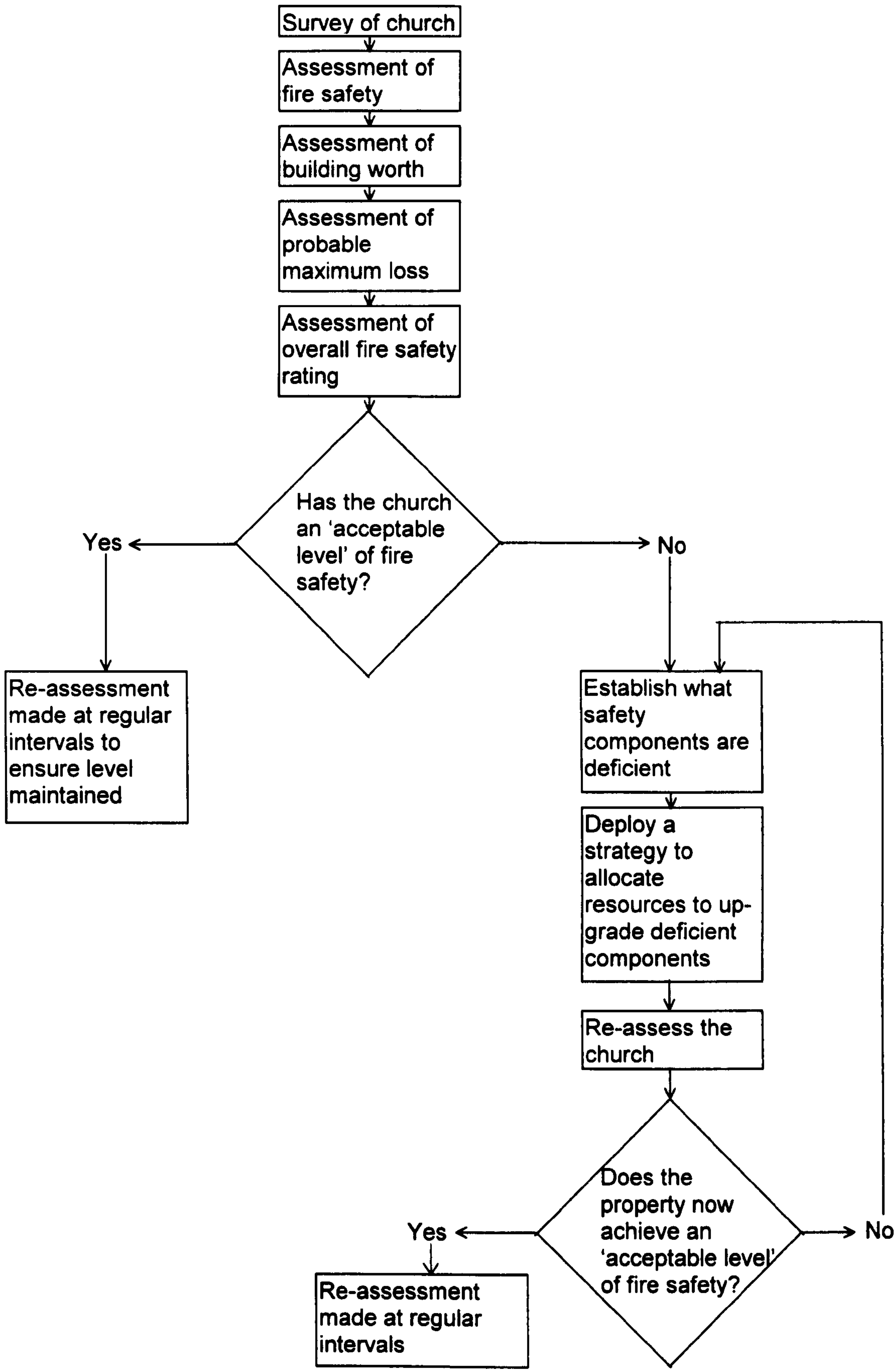
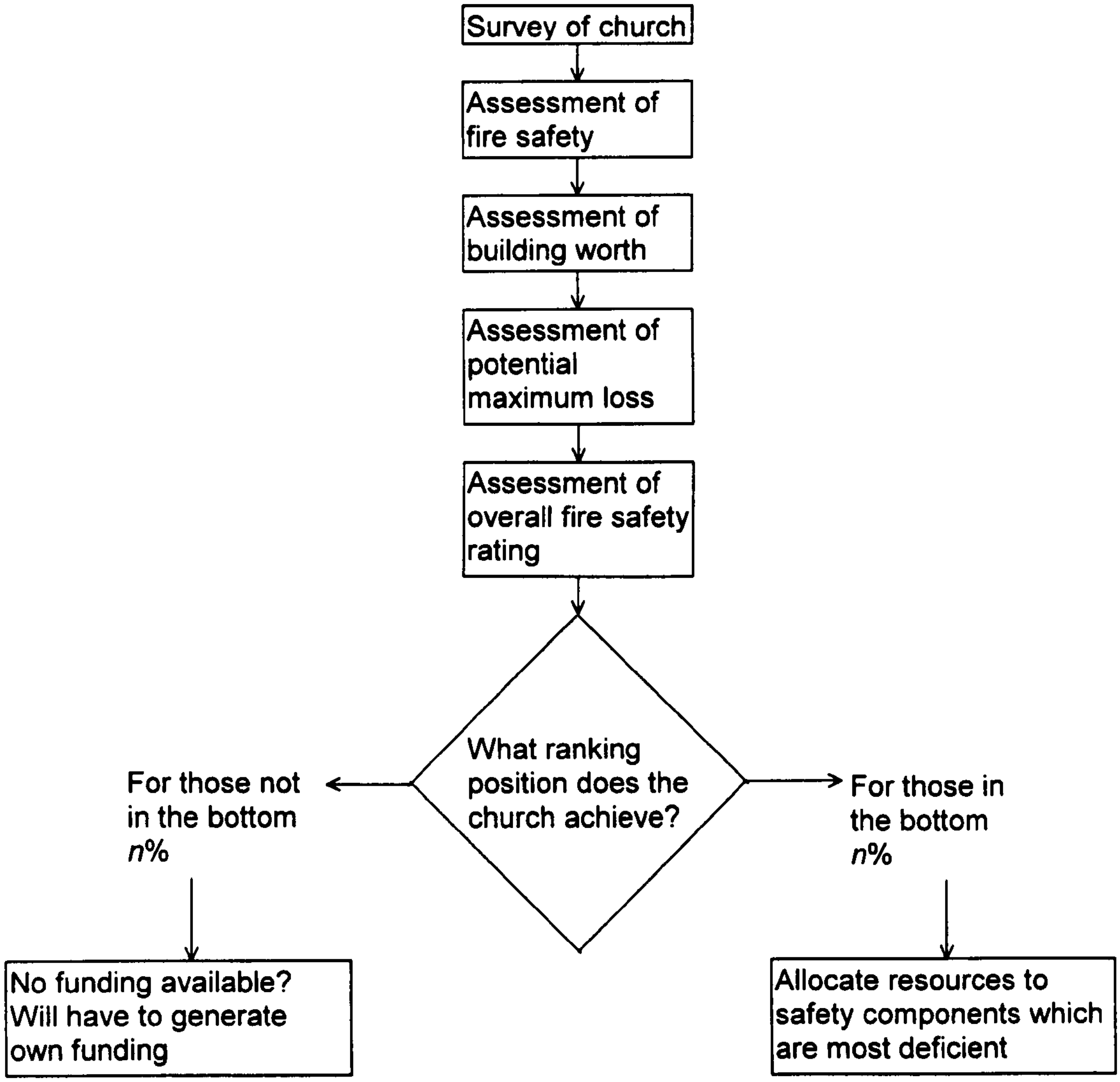


Figure 7.4: Evaluation procedure flow diagram: option 2



churches which are assessed to be in the greatest need of fire safety measures upgrades. To aid with the selection, a 'desirable level' of fire safety may be set by the diocesan management [see section 9.4.4].

At this initial stage, the evaluation procedure is achieved through a superficial knowledge based 'observational survey' conducted by an 'expert' [see section 7.3.4 and 8.5].

The prototype procedure has been developed as a paper based exercise, but it is ultimately envisaged that the final product could operate as an expert system software package. The application of artificial intelligence to fire safety decision making, however, is still very much in its infancy. The work of Galea[5], in the development of the

SMARTFIRE software package has used both fire growth simulation and knowledge engineering and represents one of the most advanced applications of artificial intelligence to fire assessment systems.

7.3 Developing the evaluation procedure

7.3.1 The evolution

Having formulated the problem and established the objectives [see the MOGSA analysis, section 7.1.2] the foundations for the evaluation procedure were cast. The first stage in the development of the procedure was to establish its operational composition. Considerable thought was given to this issue. Various investigations were conducted as detailed in chapter six, including the detailed examination of ten historic churches in the Leicester Diocese and the broader questionnaire survey of all churches in the diocese. The localised sample is considered effective for the development of the nucleus of a generic procedure, although it is possible that there will be limitations for the application of the procedure in a broader national context.

Ultimately, it was decided to utilise the approach taken on an existing 'unique occupancy' assessment scheme, the Edinburgh hospital scheme[6]. What is produced in this thesis is a redevelopment of the procedure. The application has been extensively rethought and applied to a new set of spaces that demands a unique approach. Further aspects of this procedure are unique. Firstly, the procedure assesses the fire safety of the property and not life safety, as in the hospital scheme. And secondly, the assessment of overall fire safety includes an independent evaluation of the vulnerability of fabric and contents. No other known 'unique occupancy' fire safety assessment scheme undertakes such an evaluation configuration.

In the evolution of the evaluation procedure a series of developmental problems were confronted, each of which had to be addressed and overcome. The following issues have been addressed in the sections identified.

- The development of an operational framework for the procedure [see section 7.3.2].
- The creation of an effective pro-forma to enable a successful survey method to be applied [see section 7.3.4 and chapter eight].

- The establishment of the knowledge required of the assessor, to successfully complete the survey [see chapter nine].
- The explanation and justification of the functional inter-relationships of the output variables [see section 7.3.5 and 8.6].
- The development of an effective hierarchical process of analysis to control the structure of the enquiry [see section 7.4 and chapter eight].
- The selection of a norm against which assessment can be made [see section 7.5].
- The identification of the fire safety components which contribute to the norm [see chapter eight].
- The creation of a Delphi Group and the effective elicitation of expert knowledge [see chapter eight].
- The formulation of a succinct way to present the results [see chapter nine].

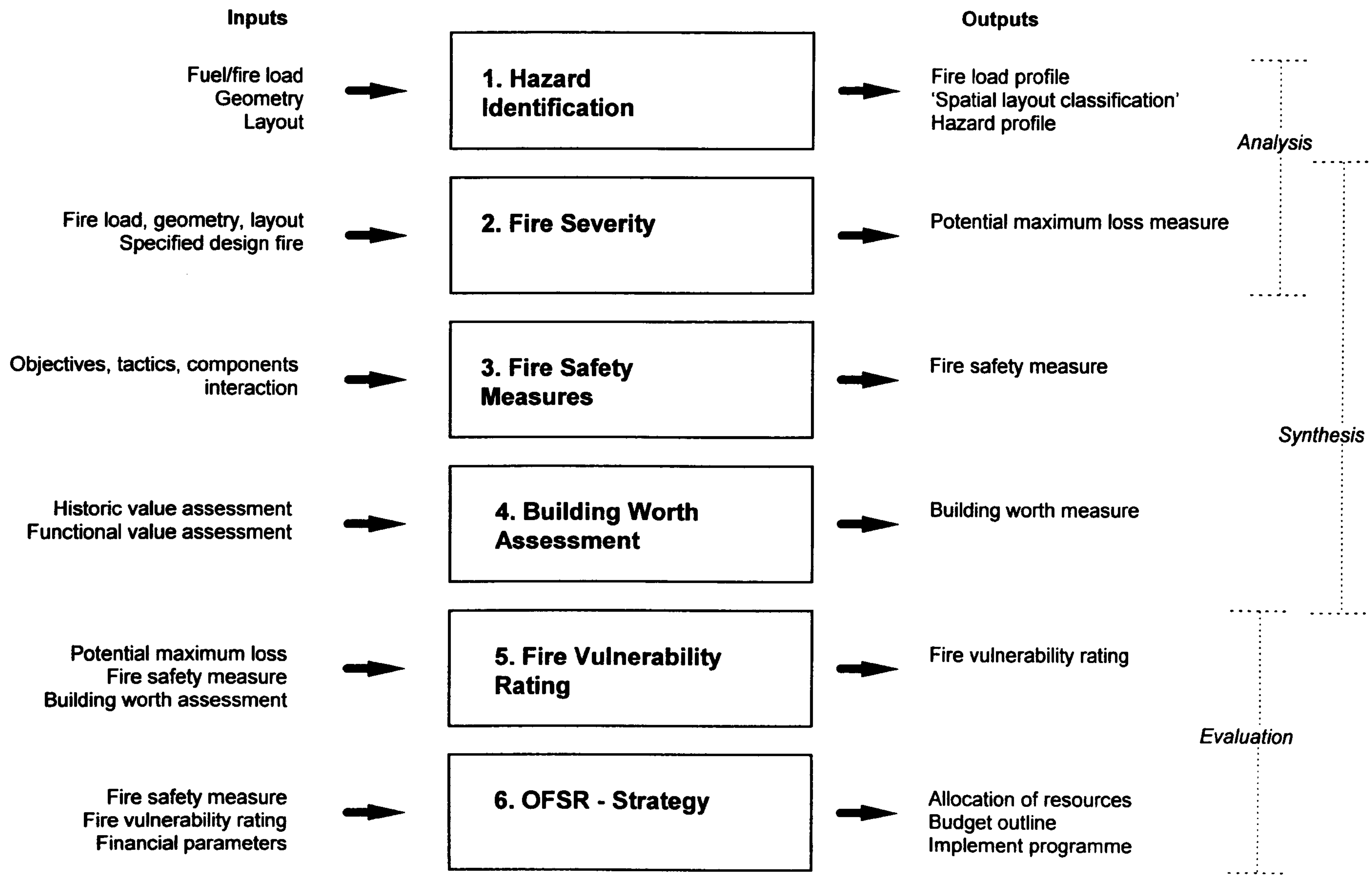
7.3.2 The operational framework

The sequencing of the evaluation procedure was developed from the operational framework, illustrated as an information flow process chart in figure 7.5. As it can be seen the framework consists of six stages. Each stage requires the input of certain data, that data is processed and a collection, or a single output is produced. In a number of cases the output from one stage is required to be input into the next stage.

The flow process chart for the evaluation procedure has been developed from and modelled on, a number of different sources. The steps have been styled on the recommended approach to the assessment of fire safety in historic buildings by Marchant[7], while the input/output aspects are based on the information bus concept as used in DD240[8] and discussed in section 5.4.2. The activities were divided into three sections. Analysis, synthesis and evaluation, as identified by Marchant[9].

It needs to be noted here that the evaluation procedure developed in this thesis starts from stage 2. The hazards are evaluated as part of stage 3 [the reason for this is explained in chapter eight]. However, the six stages represent the thought sequence behind the procedure. Stage 1 is a vital aspect of a more in-depth evaluation procedure [second level assessment]. As previously explained, features of the building which are highlighted through the first level assessment [superficial 'observational survey']

Figure 7.5: Evaluation procedure information flow process chart



will receive a more detailed assessment. The work and ideas presented in chapter six form the basis for a second level assessment.

7.3.3 The six stages of the procedure

The six stages in the flow process chart [figure 7.5] represent the sequence of activities which take place to complete the developed fire safety evaluation procedure. An overview of the stages are provided below.

Stage 1: Hazard identification

Establishing what hazards are present in each building, is the starting point for all assessments [as detailed in chapter four]. In addition, the fuel load, the geometry and layout of individual buildings need to be recorded. The survey approach adopted is detailed in section 7.3.4. The output from this stage can produce fire load profiles for the whole building or sub-assemblies within the church [see section 4.1.2.1], a spatial layout classification [see section 6.3.3] and a hazard profile based on the intensity of hazards identified. [As previously noted, such outputs would only be appropriate if a second level assessment is conducted, however].

Stage 2: Fire severity

The data gathered at stage one is used to estimate the fire severity in the building. Fire severity as explored in chapter four, can be simulated using past fire incident data, fire growth equations, or using computer models. This initial level of assessment, does not warrant such exact approaches. The assumption is made that a fire is not likely to spread beyond a 'fire tight enclosure' [see glossary of definition], so the maximum fire severity is the area of the buildings largest enclosure [previously referred to as a space, essentially it is the main worship area in most church buildings]. This is expressed as a potential maximum loss measure.

Stage 3: Fire safety measures

The level of fire safety is established by reviewing the contribution to safety of all relevant present systems. As part of that process, both the hazards and the estimation of fire severity are taken into consideration. The approach taken is based on a hierarchical framework analysis, incorporating the use of objectives, tactics and components [which is explained in section 7.4.1 and chapter eight]. The recording of hazards forms part of the survey assessment as detailed in section 7.3.4.

Stage 4: Building worth assessment

This assessment produces an evaluation of the value of the building in terms of the historic and functional value contribution to the assessment of vulnerability [see section 7.3.5].

Stage 5: Fire vulnerability rating

Stage five brings together the three previously assessed elements [potential maximum loss, fire safety measure and building worth assessment] and by setting them in the output relationship [explained in section 7.3.5] a fire vulnerability rating is generated. The inter-relationship of these variables are complex and this procedure offers an outcome which has been developed using the judgement of 'experts'.

Stage 6: Overall fire safety rating - strategy

The fire vulnerability rating is deducted from the fire safety measure to give a final overall fire safety rating, which represents a measure of the adequacy of fire safety compared to an approved 'acceptable level' [see section 9.4.4].

The overall fire safety rating dictates the level and structure of the strategy deployed to upgrade the level of fire safety [if necessary]. The strategy and its implementation forms the final element of the procedure. In terms of the practical format and content of strategies, this is not covered in the thesis. Examples of how the procedure can be used in budget control are detailed in chapter nine.

7.3.4 The input variables

Further attention is now given to explaining the survey approach adopted to record the identified input variables.

The survey data collection can be split into two sections. The data used in the assessment of fire safety and that used in the assessment of vulnerability. Decisions had to be initially made as to what level of expertise was required to collect the data and make the assessment and whether the assessment was to be made on-site or post-survey. The approach taken is detailed in table 7.1.

Table 7.1: Data collection and procedure assessment

Fire safety assessment	
Data collection: by an 'expert' - visual and 'desktop' investigated data	**Assessment:** by an 'expert', on-site
Fire vulnerability rating [potential maximum loss & building worth]	
Data collection: by an 'expert' - 'desktop' investigated data	**Assessment:** by an 'expert', post-survey calculation
Overall fire safety rating	
Data collection: --	**Assessment:** by an 'expert', post-survey calculation

Considering first the survey and assessment of fire safety. After a series of attempts at creating and testing a survey methodology which involved the quantitative collection of data by 'non-experts' and an attempt at abstracting data from a photographic survey [see chapter six for review of investigations], a survey approach was adopted, which was modelled on that used in the Edinburgh hospital scheme[10].

The worksheet survey approach involved the collection of data and the instant evaluation of the level of fire safety achieved in eighteen separate components [as developed in chapter eight]. The scores for each component are entered into a summary sheet and by simply applying the percentage contribution to fire safety [as developed in chapter eight] of each component an overall score for individual church is produced.

The completed survey score is a measure of how far short the church falls of 100% conformity with the 'collated norm' [see section 7.5]. A score of 500 indicates no deficiency. Any score less than 500 represents a measure of inadequacy compared with the 'collated norm'. For example a score of 400 is 20% deficient and a score of 300 is 40% deficient.

The data collection for the evaluation of vulnerability does not form part of the survey worksheets. A separate pro-forma [see appendix F1] was created to record the following data:

- The historic value is taken from the statutory listing grade. [This assessment in itself is a detailed qualitative assessment conducted by building conservation experts using the assessment criteria as detailed in appendix A1].

- The functional value is determined by taking the average yearly church attendance figure [This is the annual figure submitted to the diocese for funding provision. The figure does not include children under twelve, or people who attend services more than once in a day]. That figure is divided by the maximum seating capacity of the church [taken from the diocesan directory].
- The potential maximum loss is the area percentage of the largest enclosure within the building. Floor plan dimensions are either taken from available plans or by approximate pacing when conducting the fire safety worksheet survey.

Section 8.6 presents the reasoning and justification for these vulnerability variables assessment approaches.

7.3.5 The inter-relationships of the output variables

The outputs from each stage of the evaluation procedure are generated by the manipulation of the derived inter-relationships of the identified input variables. Providing a scientific justification for these relationships is not possible. The inter-relationships between variables are complex and the procedure offers a 'first cut' outcome which has been developed using the judgement of 'experts' only (a Delphi group). [see chapter eight for a detailed explanation of the role of the Delphi group].

The identified variables that contribute to the enquiry are detailed in table 7.2. The logic behind the layout of the variables is explained.

The evaluation procedure uses two key factors to produce an assessment of vulnerability; loss impact on the property and the potential extent of the loss from fire [see figure 7.6 for variable layout]. The loss impact of losing a church is seen to have a direct relationship to vulnerability. Loss impact does not judge the physical adequacy of protection from fire damage, but the vulnerability to emotional hurt. The combination of the two variables of historic value [HV] and functional value [FV] produce the impact loss. Here the assumption is made that as the historic value, in terms of antiquity and uniqueness of the fabric and content of a church increases, the impact from a loss increases and as the functional usage increases, the building becomes valuable to more people and a loss is felt more widely.

In assessing the potential extent of the loss from fire [see figure 7.6 for variable layout],

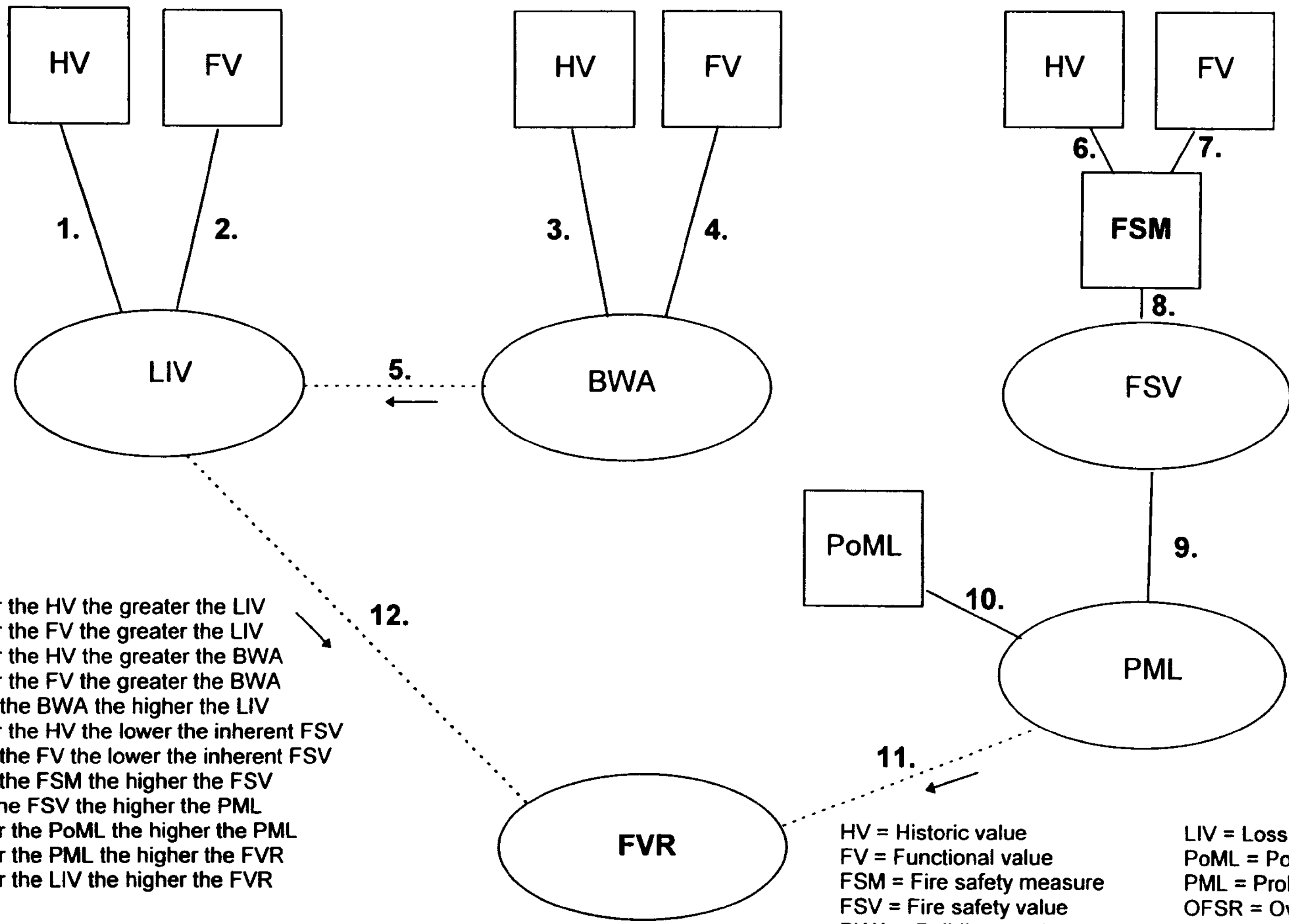
Table 7.2: The identified variables that contribute to the enquiry

Variables	Definition	Data source or method of calculation
Historic value [HV]:	The historic value of the property	Derived from the statutory listing
Functional value [FV]:	The average use of the building	Estimated by dividing the maximum seating capacity by the average service attendance
Fire safety measure [FSM]:	The measure of the level of fire safety	Assessed by eighteen worksheet components and their contributory values to fire safety
Fire safety value [FSV]:	The adjusted FSM, considering the effect of the historic and functional value	FSM - [HV + FV]
Building worth assessment [BWA]:	The combination of the historic value and functional value	HV + FV
Loss impact value [LIV]:	This is the impact of loss which is close coupled to the BWA.	BWA = LIV
Potential maximum loss [PoML]:	This is considered to be the largest potential fire that could occur.	The largest single enclosure in the building expressed as a percentage of the whole building
Probable maximum loss [PML]:	The potential maximum loss, adjusted by the level of fire safety [FSV] present	PoML - FSV
Fire vulnerability rating [FVR]:	The combined assessment of the loss impact of the property and the potential extent of the loss from fire	LIV + PML
Overall fire safety rating [OFSR]:	A measure of the adequacy of fire safety [of the fabric and contents of the property]	FSM - FVR

the assumption is made that the potential maximum loss from fire is not likely to exceed the area of the largest enclosure. In addition, maximum fire loss is likely to be adjusted by a factor which represents the level of fire safety [FSM] in the building, which in itself is reduced by the assessed historic value and functional value to give a fire safety value [FSV]. Here the assumption is again made that as the historic and functional value increases the greater the loss impact. Thus the effectiveness of the fire safety measures are reduced. The potential maximum loss [PoML] less the fire safety value [FSV] represents the immediate balance between the quantity of damage that the fuel and fire safety systems will allow. This is expressed as the probable maximum loss [PML].

The OFSR balances the vulnerability [FVR] of the church building to fire against the level of fire safety present [FSM]. The evaluation procedure seeks a positive overall fire safety

Figure 7.6: Variable inter-relationships for the assessment of vulnerability

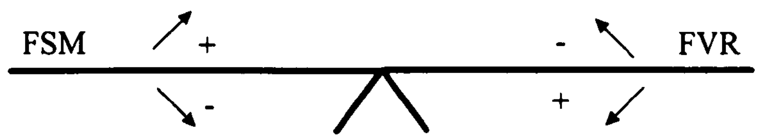


1: The greater the HV the greater the LIV
2: The greater the FV the greater the LIV
3: The greater the HV the greater the BWA
4: The greater the FV the greater the BWA
5: The higher the BWA the higher the LIV
6: The greater the HV the lower the inherent FSV
7: The higher the FV the lower the inherent FSV
8: The higher the FSM the higher the FSV
9: The lower the FSV the higher the PML
10: The higher the PoML the higher the PML
11: The higher the PML the higher the FVR
12: The higher the LIV the higher the FVR

HV = Historic value
FV = Functional value
FSM = Fire safety measure
FSV = Fire safety value
BWA = Building worth assessment
LIV = Loss impact value
PoML = Potential max. loss
PML = Probable max. loss
OFSR = Overall fire safety rating
FVR = Fire vulnerability rating

rating score in which the adequacy of fire safety is suitable for the assessed vulnerability of the building. Thus, as the fire vulnerability rating increases a higher fire safety measure score is required to compensate for the high vulnerability factor and conversely, for those churches with a low fire vulnerability rating a lower fire safety measure is required [see figure 7.7]. For those churches which receive a negative balance score, an FSM score upgrade improvement is necessary. A minimum FSM score is also suggested, regardless of the FVR to ensure all churches do not exceed a 60% norm deficiency [see section 9.4.4].

Figure 7.7: The balance scale



7.4 The hierarchical process of analysis

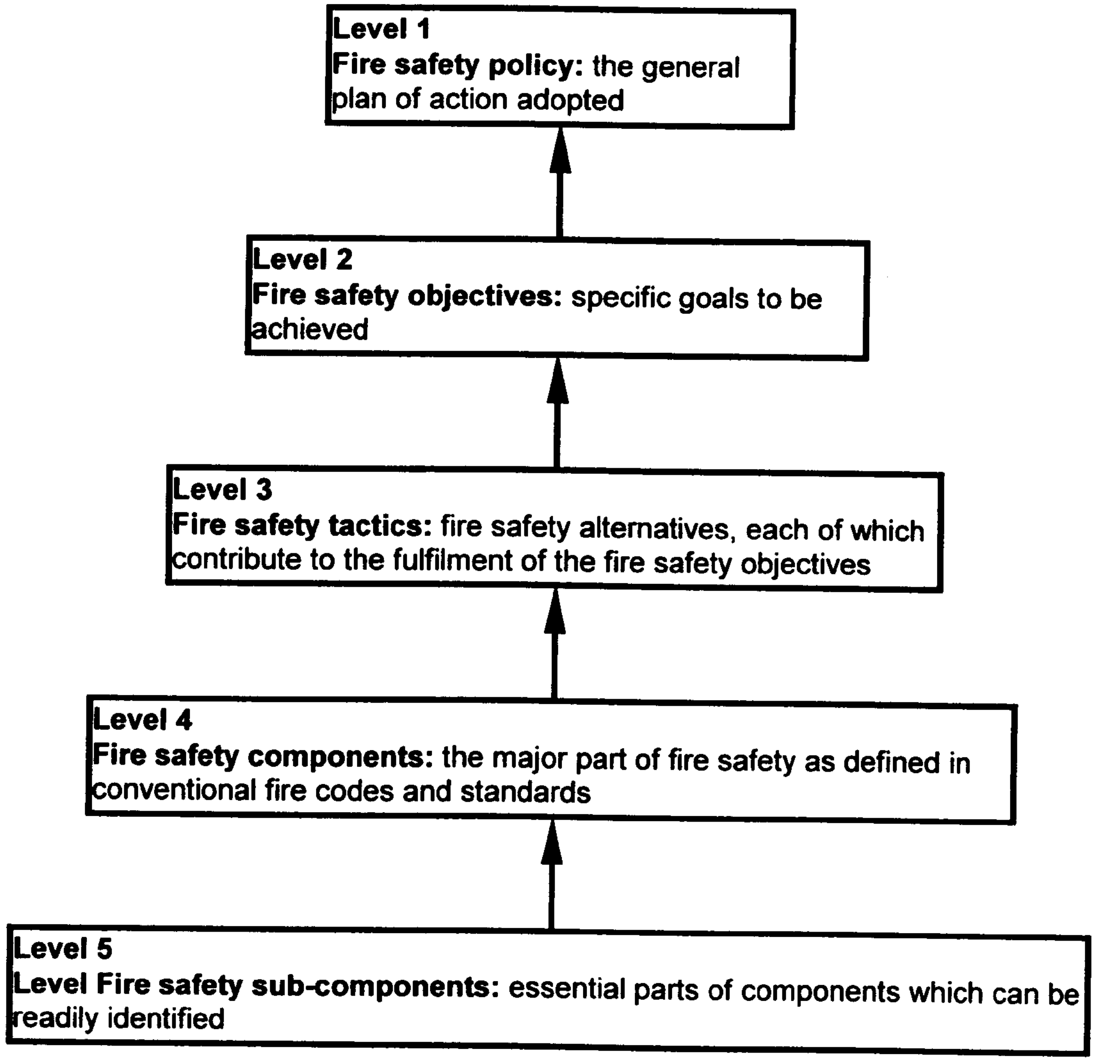
Further to the outlining of the operational framework and the input and output variables of the procedure, this section discusses the hierarchical process of analysis used to model the fire safety assessment enquiry in question. [the MOGSA analysis [section 7.1.2] and the proposed 'artifact dissection' framework [section 6.6.1] are examples of hierarchical processes of analysis already used in the thesis].

7.4.1 Hierarchical framework

Watts[11] describes the process of fire safety decision making as very often having to be made under conditions where the data is sparse and uncertain. The technical parameters are very complex and normally involve a network of interacting components, the interactions generally being non-linear and multi-directional. Such problems can be effectively presented in a hierarchical representation of the problem.

A hierarchical process of analysis descends from an apex, an overall objective or policy, down through sub-objectives and further down to forces which affect these sub-objectives [see figure 7.8]. Saaty[12] identifies four advantages of using hierarchies as an analysis tool:

Figure 7.8: Decision levels of a fire safety hierarchy



1. Hierarchical representations of a system can be used to describe how changes in priority at upper levels affect the priority of elements in lower levels;
2. They give great detail of information on the structure and function of a system in the lower levels and provide an overview of the factors and their purposes in the upper level;
3. Natural systems assembled hierarchically, evolve much more efficiently than those assembled as a whole;
4. They are both stable and flexible; stable in that small changes have small effect and flexible in that additions to a well-structured hierarchy do not disrupt the performance.

7.4.2 The five steps of the hierarchy

For this enquiry, the hierarchical framework of fire safety developed in the Edinburgh hospital scheme[13] is adopted. The hierarchy provides an effective abstraction of the structure of the enquiry, which enables the functional interactions of its components and their impacts on the entire system to be studied.

The hierarchy defines the problem from top to bottom in a series of decision levels as illustrated in figure 7.8. The top level element is the policy; a statement, in broad terms, stating what is to be accomplished by developing the evaluation procedure. In this case, the mission statement defined in section 7.1.2 represents the policy. The objectives of fire safety are the specific goals to be achieved, which have now been confirmed as being the objectives of property safety and mission continuity. Tactics are the overall actions, which when conducted successfully, will fulfil the objectives. Stollard[14] has defined five generic fire safety tasks to fulfil the objectives of life safety and property protection [table 7.3].

Table 7.3: Generic tactics of fire safety

Tactics	Definitions
Prevention	Ensuring that fires do not start by controlling ignition and fuel sources
Communication	Ensuring that if ignition occurs, the occupants are informed and any active fire systems are triggered
Escape	Ensuring that the occupants of the building and the surrounding areas are able to move to places of safety before they are threatened by heat and smoke
Containment	Ensuring that the fire is contained to the smallest enclosure limiting the amount of property likely to be damaged and threat to life safety
Extinguishment	Ensuring that the fire can be extinguished quickly and with minimum consequential damage to the building

For this enquiry, the tactics have yet to be determined [see chapter eight].

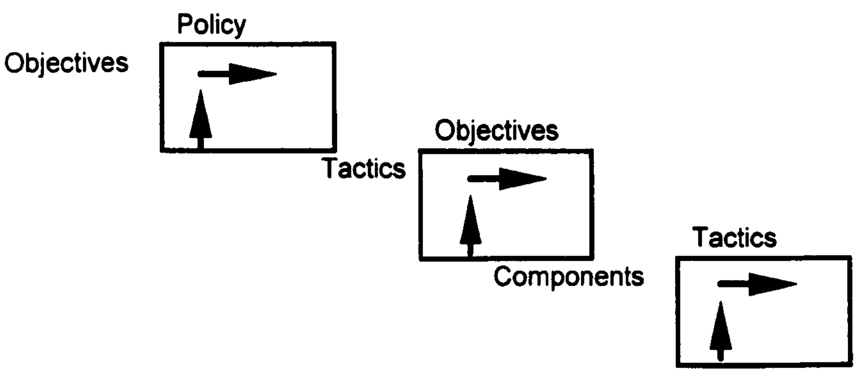
The components are the weapons that are to be used to achieve fire safety. The number of components is limitless and depends on how they are categorised and how the sub-components are defined. As well as the obvious fire safety components of active fire safety measures, components of fire safety will range from the building itself and its content through to the occupants of the building and the buildings management. The elements for each level of the hierarchy to be developed for this particular fire safety enquiry have yet to be defined.

7.4.3 Hierarchical matrices

Saaty[15] identified two key stages in setting up a hierarchical framework. Firstly, to structure the function of a system hierarchically [as achieved above] and secondly, to select a technique to measure the impact of any element in the hierarchy.

To achieve this the hierarchy uses a series of matrices to model the relationship between different levels of the hierarchy. As can be seen in figure 7.9 a matrix of policy versus objectives defines a fire safety policy by identifying the specific objectives which are held desirable. In turn, a matrix of objectives versus tactics identifies the relationship of these elements and a matrix of tactics to components identify the contribution of the hardware to the tactics.

Figure 7.9: Hierarchy matrices



The multiplication of matrices enables the contribution of components to the overall fire safety policy to be calculated. The ability to generate explicitly defined relationships makes the approach particularly appealing. This principle is adopted in chapter eight.

7.5 Establishing the normative documentation

As identified in the list of developmental problems [section 7.3.1], it was necessary to establish a norm against which assessment can be made. This is detailed below.

Any assessment procedure requires the outcome to be set against a comparator or norm to enable a judgement of deficiency to be made. Marchant[16] identifies two approaches:

- The owner should define the level of loss due to fire which is acceptable.
- The fire safety standard should be compared to that expected by codes and regulations which control new buildings.

In considering the former, the definition of an acceptable level of fire loss can be determined in terms of area damaged, items lost or in terms of monetary loss. With such an approach it is not possible, to establish an uniform acceptable loss across all churches as each building owner has a different perception. In addition, an assessment of a potential loss is very complex.

Rasbash[17] identifies three approaches to the judgement of minimum safety: by comparison to a norm which has been shown by experience to be safe enough; by designing a system so that the expected frequency of deaths from fire does not exceed a certain specified frequency or by designing a system with an optimum cost effectiveness with regard to fire safety. Rasbach suggests that the first of these is the only practical way of proceeding in many situations due to the high complexity of fire safety.

From the review of options, it was decided that a fire safety standard set in a normative document presented the most effective comparator for this enquiry.

7.5.1 Examination of codes and guidance documents

For churches, with respect to the preservation of solely fabric and content, no statutory regulations exist, although aspects of life safety legislation are applicable in parts. As an alternative, guidance documents were sourced from a number organisations. A review of these documents revealed, however, that definitive guidance on all aspects of fire safety in churches was not available in one document. The check lists and guidance sheets issued by the EIG provided the most comprehensive collection of fire safety requirements, but, certain required aspects were not addressed, such as fire spread and smoke control, fire brigade arrival and access, and retrieval training and practice. Due to this, a collection of documents were assembled, which together covered all the required elements of church property fire safety. The following documents were used:

- Ecclesiastical Insurance Group [EIG], **Check Lists and Guidance Sheets**, 1997
- Fire Protection Association [FPA], **Prevention and Control of fire in Cathedrals and churches**, 1973
- Churches Main Committee [CMC], **Fire Precautions Guide**, 1998
- National Fire Protection Association [NFPA], **912 Fire Protection in Places of Worship**, 1993
- The Arson Prevention Bureau [APB], **Assessment of Arson Risk in Places of Worship**, 1998
- Council for the Care of Churches [CCC], **It Won't Happen To Us**, 1970
- Council for the Care of Churches [CCC], **Lighting and Wiring of Churches**, 1973
- Fire Prevention Association [FPA], **Heritage Under Fire**, 1995
- **Part B of the Building Regulations, 1991**
  - B1 Means of escape
  - B2 Internal fire spread [lining]
  - B3 Internal fire spread [structure]
  - B4 External fire spread
  - B5 Access & facilities for the fire service
- Home Office, **Standards of Fire Cover** [Handbook for Fire Engineers 1989]
- In addition, a series of British Standards are referred to [see appendix F2]

7.5.2 The established the 'collated norm'

Having accepted the above collection of documents as a 'collated norm', as a standard for assessment, the relevant aspects of each document [apart from the British Standards] were brought together into one document [see appendix F2]. The selection of the elements was made through a logical analysis of the content of the documents. As most of the documents provided guidance information and not mandatory instructions, all information is couched with terms such as 'strongly recommended', 'wherever possible' and 'preferably'. Thus the single 'collated norm' can be considered to be the ultimate best practice standard for fire safety in respect to the protection of fabric and content.

Churches that conform one hundred percent to the norm can be considered to have a perfect level of fire safety. This situation, however, is extremely unlikely with the current level of fire safety practices in parish churches. The 'collated norm' has been set at this currently unattainable standard, to illustrate the short fall, or deficiency of fire safety in churches. For most churches, their level of vulnerability will not warrant a perfect level of fire safety. A deficient score may be deemed acceptable [see section 9.4.4 for further clarification].

7.6 Summary

This chapter has initially presented the justification for the development of the fire safety evaluation procedure. Four potential users of the output from the procedure are identified, the diocesan management, the PCC or guardian of individual churches, the fire engineer or insurance surveyor and building contractors or other contractors working on the property. It is anticipated that the flexibility of the procedure shall enable it to operate as a versatile tool capable of fulfilling the individual user requirements.

This research programme focuses on the embryonic development of the evaluation procedure and takes the development through to a pilot test application. The prototype procedure has been developed as a paper based exercise, using 'expert' assessors, however, it is ultimately envisaged that the final product could operate as an expert based computer package.

Fire [SEPC]] is designed to assess the overall fire safety rating [OFSR] of individual properties. The procedure balances the vulnerability of church contents and fabric to fire against the fire safety of the property.

The vulnerability of church buildings is assessed by evaluating the loss impact of the property and the potential extent of the loss from fire, while the procedure generates a series of elemental component scores which are brought together to produce a fire safety assessment score for individual churches. This score, is in turn, set against an agreed benchmark referred to as a 'collated norm'.

The operational framework for the evaluation procedure consists of six stages of activity, hazard identification, fire severity, fire safety measure, building worth assessment, fire vulnerability assessment, fire vulnerability rating and overall fire safety rating - strategy.

Data input into the evaluation procedure is achieved through a worksheet survey approach. Assessment is made both on-site and post-survey. The outputs from each stage of the evaluation procedure are generated by the manipulation of the derived inter-relationships of the identified input variables. Providing a scientific justification for these relationships is not possible. The inter-relationships between variables are complex and the procedure offers a 'first cut' outcome which has been developed using the judgement of 'experts' only (a Delphi group).

The procedure has been developed using a hierarchical process of analysis, consisting of five levels of assessment. A series of matrices are used to model the relationship between different levels of the hierarchy.

The operational mechanics of the evaluation procedure have now been covered, but before Fire[SEPC] can function as an evaluation procedure a method of placing contribution weightings to process variables needs to be sought. This is detailed in chapter eight.

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CHAPTER EIGHT

ACQUISITION OF PRIOR KNOWLEDGE

8. ACQUISITION OF PRIOR KNOWLEDGE

8.0 Introduction

In this chapter the Delphi approach to judgement acquisition is introduced, discussed and its application described. The methodology for the Delphi sessions is covered. The outcome of the Delphi sessions are detailed and the creation of the component worksheets are explained.

8.1 The Delphi approach to judgement acquisition

8.1.1 The Delphi technique

The Delphi Technique is a tool used for mediation and consensus building activities. It is defined by Linstone and Turoff[1] as 'a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem'.

In this technique, experts from a variety of related fields are recruited and their opinions on various questions recorded. The classic approach entails sending a series of questionnaires to the participants who never meet face-to-face. The divergences in opinion are repeatedly re-interrogated until common agreement is reached.

8.1.2 The evolution of the Delphi technique

The ironical name 'Delphi' is taken from the ancient Greek oracle at Delphi which was famous for the ambiguity of its answers![2]

The Delphi concept is a spin-off of United States defence research, the first Delphi projects being an Air Force sponsored Rand Corporation study conducted in the early 1950's[3]. The subject of the first study was the application of expert opinion to the selection of an optimal USA industrial target system and the estimation of the number of A-bombs required to reduce the munitions output to a prescribed amount. The alternative method of handling this problem at the time would have involved a very expensive data collection process. The original justification for this first Delphi study is still valid for the application of the Delphi process today. Namely, when accurate information is unavailable or expensive to obtain, or when evaluation models require subjective inputs to the point where they become the dominant parameters.

As details of the Delphi process started to appear in published articles during the late fifties and early sixties interest increased outside the defence community. Early civilian American studies used the Delphi technique for technical forecasting. Such studies included work by Dalkey and Helmer[4] in 1963, Cetron[5] and Decker[6] in 1969 and Certon and Ralph[7] in 1971.

Today the technique is utilised in Western Europe and the Far East and has found applications in problems facing the environment, health, transportation and other related fields.

8.1.3 Application of the Delphi technique in fire engineering

As a tool used in fire safety evaluation, the first pure application of the Delphi technique was the Fire Safety Evaluation Scheme for Health Care Facilities in USA, conducted by Benjamin in 1979[8]. This was followed by a similar scheme developed for UK health buildings by Marchant et. al. in 1982[9]. Further fire safety evaluation schemes for specific building types have since used the Delphi technique including schemes developed by Shields et.al.[10] for dwellings, by Mohd Idris[11] for educational establishments, and Parks et. al.[12] for telecommunication facilities.

Other 'points schemes' [defined and discussed in chapter five], have used committees or 'wise men' type groups to collate expert opinion, but they are not considered by the author to be a pure Delphi approach. Probably the earliest example being the Fire Prevention Panel of BINC used to generate legislation and minimum acceptable standards for means of escape[13].

This enquiry adopts the Delphi approach used in the Edinburgh hospital scheme[14] and the evaluation of safety in canal tunnels undertaken by Stollard[15].

8.1.4 An evaluation of its merits and demerits

The Delphi technique used as a consensus tool has both merits and demerits. In terms of demerits, a series of potential methodological problems have been clearly identified by both Shields et. al. [16] and Dodd and Donegan[17].

Shields et al. reviewed the application of the Delphi approach under a number of headings. The key points are presented below:

Delphi reliability: The technique is very hard to test for reliability as it would require two groups of experts to be furnished with identical statements, but unfortunately no two studies are the same.

Questionnaire design: Poorly designed questionnaires can cause bias and distortion in the respondents' answers.

Expert: Delphi researchers rarely define the term 'expert' or set clear criteria for individual 'expert' selection. Shields notes that in reality 'expert' groups are usually made up from:

1. Persons who are involved in the general area of study and possess some minimum formal criteria.
2. Persons who are known by the researcher.
3. Persons who by reputation are informally known by the researcher.
4. Persons who are readily available or can be pushed into service.

Consensus: Again most Delphi studies do not clearly define the approach taken.

Assignment of values: Frequently a scale of zero to five has been used to assign relative values of importance to the elements of a fire safety hierarchy, referred to as a 'Likert type' scale [see glossary for definition]. Shield questions whether such a scale can be validated and the level of measurement it achieves.

Stability: Shields offers the option of considering the stability of a Delphi group rather than the consensus. The approach sets upper and lower quartile limits within which the consensus sits. It is then recommended that a 15% change level is set. So if there is less than a 15% change between Delphi rounds then stability is reached.

Like Shields et.al., Dodd and Donegan also express some fundamental concerns in the assessment of opinions by a panel of experts. Firstly, the authors express concern about the scale used in the measurement process. They emphasis the fact that the 'Likert type' zero to five scale implies that all points on the scale are equally likely, but demonstrate that is not the case as the mere inclusion of particular systems or procedures indicates that they are likely to have a positive score and therefore zero is a less likely than other scores.

Secondly, the authors question whether the scores should be normalised before the processing stage to eliminate personal bias from the scores. The authors present both a top-down and a bottom-up technique for the determination of minimum component behaviour in the selection of norm vectors used in survey analysis.

In contrast to the methodological problems identified, the Delphi technique does contains many merits if used with knowledge and skill and with a correct understanding of its application and limitations.

Marchant states that there is little wrong with the Delphi technique if the members of the group are knowledgeable[18]. Harmathy also supports the approach, 'a dedicated Delphi group could provide an invaluable service to fire technology by establishing the consensus necessary to bridge some grey areas in fire science'[19]. A study by Martino[20] concluded that the Delphi estimation is not a chaotic process, but one that processes some underlying order.

As stated by Linstone and Turoff[21], the technique should not be used as a decision making tool, but as a decision-analysis tool. The decision should be made by one individual and the role of the Delphi technique should be to provide the best possible information and ensure that all the options have been considered prior to decision making.

The imposition of the Delphi technique on a particular problem is not the correct approach. Linstone and Turroff[22] identify a series of key properties, of which if one or more are present, the application of the Delphi technique may be appropriate. Namely:

- The problem under consideration does not lend itself to precise analytical techniques, but can, nevertheless, benefit from subjective judgement on a collective basis;
- People with diverse backgrounds with respect to experience and expertise, may be required to contribute to the solution of complex problems;
- More people may be required to contribute than can effectively interact in a direct contact situation;
- Time and cost may rule out frequent group meetings;
- Internal politics may colour the communication process;
- The efficiency of direct contact may be enhanced by a supplemental group communication process;

- In a committee environment there may be the an undue influence exerted by members with strong personalities.

As a subjective judgement consensus tool the Delphi process has a number of key merits. Dalkey[23] identifies these as:

1. Anonymity - This is effected by the use of questionnaires or other formal communication channels thereby reducing the impact/effect of dominant individuals;
2. Controlled feedback - This is achieved by conducting the exercise in a series of rounds between which a summary of the results of the previous round is communicated to the participants;
3. Statistical group response - This is a device to assure that the opinion of every member of the group is represented in the final response. It is also a method of reducing group pressure for conformity.

8.1.5 Justification for its use

For the enquiry in question a consensus technique was sought which would contribute effectively to the rationalised systematic approach adopted. As identified by Linstone and Turroff above, the problem under consideration in this particular case did not lend itself to precise analytical techniques, but could benefit from subjective judgement on a collective basis.

The Delphi technique was initially investigated as a potentially suitable approach as the technique has been previously successfully applied to other fire safety evaluation problems as outlined in section 8.1.3. The decision to use the Delphi technique was only taken after a review of other consensus building tools was comprehensively undertaken. These included the normal group technique, interpretative structural modelling, idea writing process and concept mapping as identified by Kotlas[24].

It was decided to conduct the Delphi process over a series of sessions in which the participants physically assembled in one location and not to use the classical mail question dispatches. This was for a number of key reasons:

1. There was a need to cut down on time. The two half day face-to-face Delphi meetings achieved what was required when a classic Delphi postal three stage approach was expected to take 30 to 45 days[25].
2. The face-to-face Delphi approach was most effective because the participants were

local, the time was limited, and so was funding [the cost of tea, coffee and sandwiches as opposed to the cost of stamps, envelopes and additional administration].

3. The process could be developed at a speed, controlled by the participants and not by the rigours of the process.

4. As the number of participants was small the drop-out of members could not be afforded. This is a recognised problem of the classical mail distribution approach.

5. It allowed the sharing of information and reasoning amongst participants. This was particularly helpful to clarify issues and to discuss other relevant subjects not included in the Delphi questionnaires. Equally, independent thinking was still maintained by the effective management of the sessions. No communication was allowed during the completion of the questionnaires. The participants were also carefully picked to provide a broad analytical perspective.

It must be stressed that the approach taken was not a 'committee process' or a 'panel group' [see glossary of definitions] and thus the problems associated which such approaches were avoided. Linstone and Turoff[26] note the typical problems of a 'committee process' as:

- The domineering personality, or outspoken individual that takes over the 'committee process';
- The unwillingness of individuals to take a position on an issue before all the facts are in or before it is known the majority's opinion;
- The difficulty of publicly contradicting individuals in higher positions;
- The unwillingness to abandon a position once it is publicly taken;
- The fear of promoting an uncertain idea that might turn out to be idiotic and result in a loss-of-face.

While developing and conducting the Delphi technique for this specific application every attempt has been made to address the methodological problems identified by Shields et.al. in section 8.1.4. The approach taken is detailed in the remaining sections of this chapter.

8.2 Delphi session methodology

8.2.1 Meeting methodology and management

Two face-to-face Delphi group sessions were conducted in the Leicester School of

Architecture, at De Montfort University during August 1998. Each session lasted approximately three hours. The Delphi group was used to consider a range of issues relating to the development of the fire safety evaluation procedure. As illustrated in the session methodology diagram [figure 8.1], the first Delphi session started by setting fire safety in the context of building performance and destructive agents. [select results are presented in chapter two]. The sessions then addressed the main element of the procedure, and the classification and weighting of the various parameters of the hierarchy of fire safety. The Delphi group was finally asked a series of questions on the building worth and loss impact of parish churches.

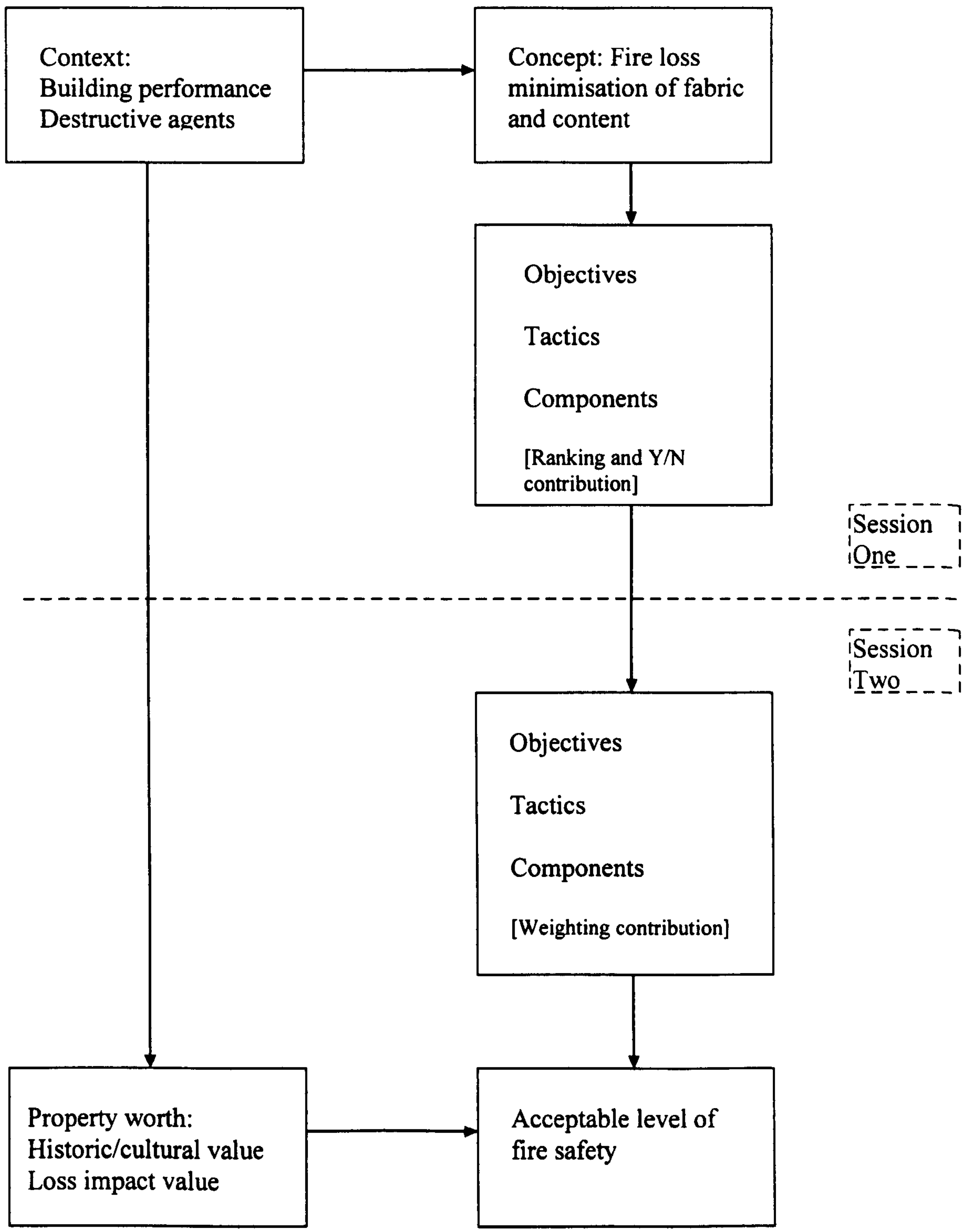
The programme for each session [appendix G1] was carefully scripted by the author. The sessions consisted of a series of short introductions followed by the completion of various sets of questions [appendix G2]. While the questionnaires were being completed care was taken to ensure that the participants did not discuss their responses. The profiles of the responses were analysed either during a break in the session or between the two sessions. Answers which did not show a clear consensus were re-presented to the group in the next series of questions.

8.2.2 Selection of participants

It was necessary to bring together a Delphi group consisting of participants which represented the interests of a those involved in the use, management, maintenance and preservation of churches as well as experts in fire and fire engineering. It was considered that individuals fell into two groups, those which had a first hand involvement, which were categorised as sitting in an inner circle and those who had a less consistent or professional involvement with churches. For example, contractors such as stone masons and electrical engineers and also the congregation and local residents. These were categorised as sitting in an outer circle. It is acknowledged that individuals from both circles have a valid input to make, but principally for practical reasons, it was decided to use only those experts most closely involved i.e. those in the inner circle to form the Delphi group.

Each participant was invited to take part in the Delphi group due to their expertise [see table 8.1]. Every attempt was made to create a balanced group with a blend of experts represented. [Unfortunately, one member of the group dropped out at the last minute, an ecclesiastical insurance surveyor from the Ecclesiastical Insurance Group. However, the

Figure 8.1: Delphi sessions methodology



view of the insurance industry was sought in a separate meeting with a representative from the EIG, conducted between Delphi sessions.]

Table 8.1: Delphi group participants

Participant	Profession/expertise
Rev. Jane Curtis/Rev. Dr Roy Seden	Vicars
Mr Terry Bray	Fire prevention officer
Dr Eric Marchant	Fire safety engineer & architect
Dr Arthur Lyons	Material scientist
Ms Melanie Clamp	Ecclesiastical architect
Dr David Watt	Conservation officer
Prof. Peter Swallow	Historic building surveyor

8.3 Presentation and discussion of the results

Results of the Delphi group knowledge acquisition sessions are detailed in two parts. Here the decisions relating to the hierarchy of fire safety are presented while consensus relating to the vulnerability of church properties is covered in section 8.6.

8.3.1 Inter-relationship between the hierarchy of fire safety

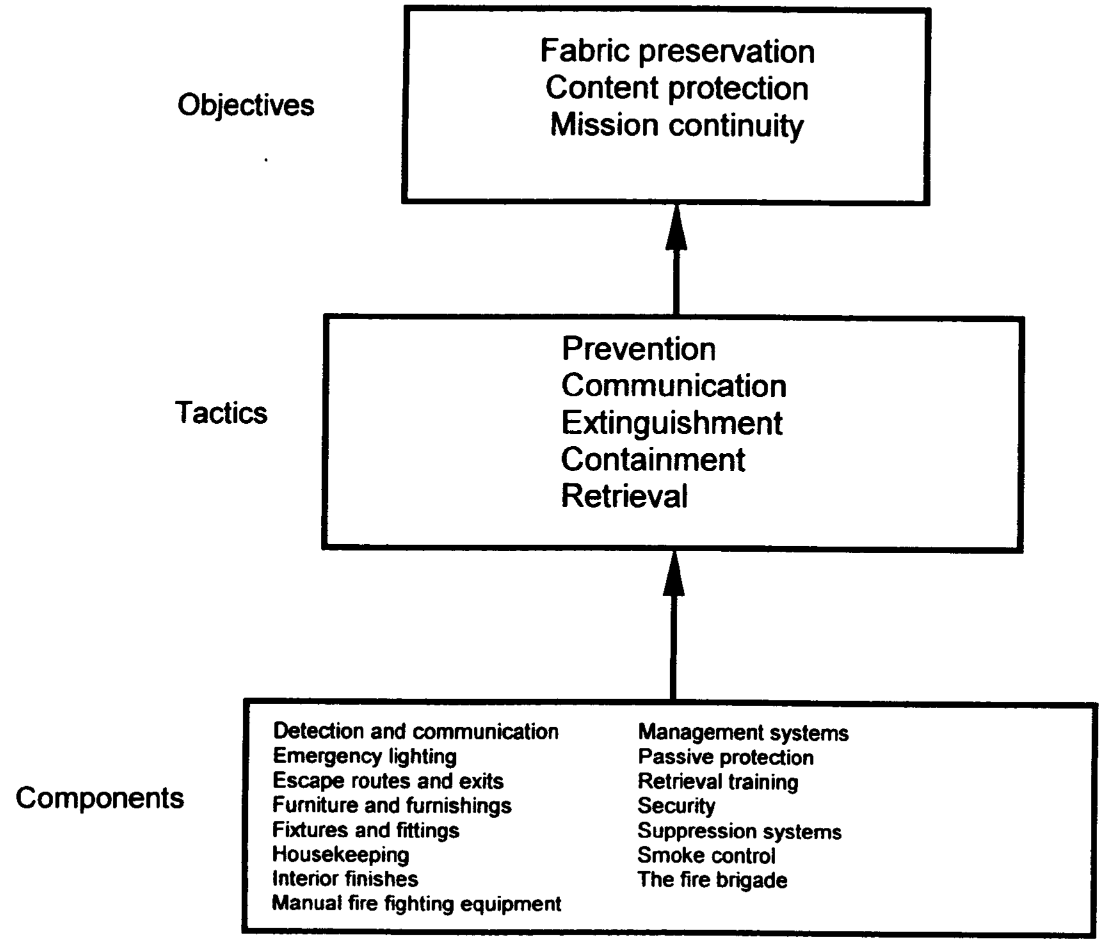
As detailed in chapter seven, a hierarchy of fire safety is to be adopted consisting of five levels, policy, objectives, tactics, components and sub-components. Using the prior knowledge of 'experts' in respect to this 'unique occupancy' the elements of levels two to four of the hierarchy were developed and evaluated.

As an initial step a proposed hierarchy of fire safety for the property protection of parish churches was developed by the author [see figure 8.2]. The initial hierarchy was then used as a starting point from which the view of the Delphi group was sought. The generation of objectives, tactics and components by the Delphi group was considered not to be realistic in the time available.

The Delphi group was asked to review the initial proposed hierarchy in a top-down approach of decision making complexity starting with the objectives and ending with the components. The process was conducted in a series of stepped operations [the results from which are detailed in sections 8.3.2 to 8.3.4 and 8.4]:

- Firstly the Delphi group was asked to review the proposed hierarchy content and to delete, add or approve the initial content, including the titles and definitions of elements.

Figure 8.2: Initial proposed elements of the hierarchy



- Secondly, the Delphi group was asked to rank the agreed content of the objectives, tactics and components in order of their priority in respect to their degree of relevance.
- Thirdly, the Delphi group was asked to indicate tactic to objective and component to tactic contributions as a yes or no response.
- And fourthly, the Delphi group was asked, on a scale of one to ten, to indicate the absolute importance of each tactic to objective and component to tactic.

8.3.2 Evaluation of the objectives

The three proposed objectives and their definitions were all approved by the Delphi group as having a contribution to the overall concept of the procedure and fire loss minimisation of fabric and content. The priority order was as shown below.

Table 8.2: The agreed objectives and their priority ranking

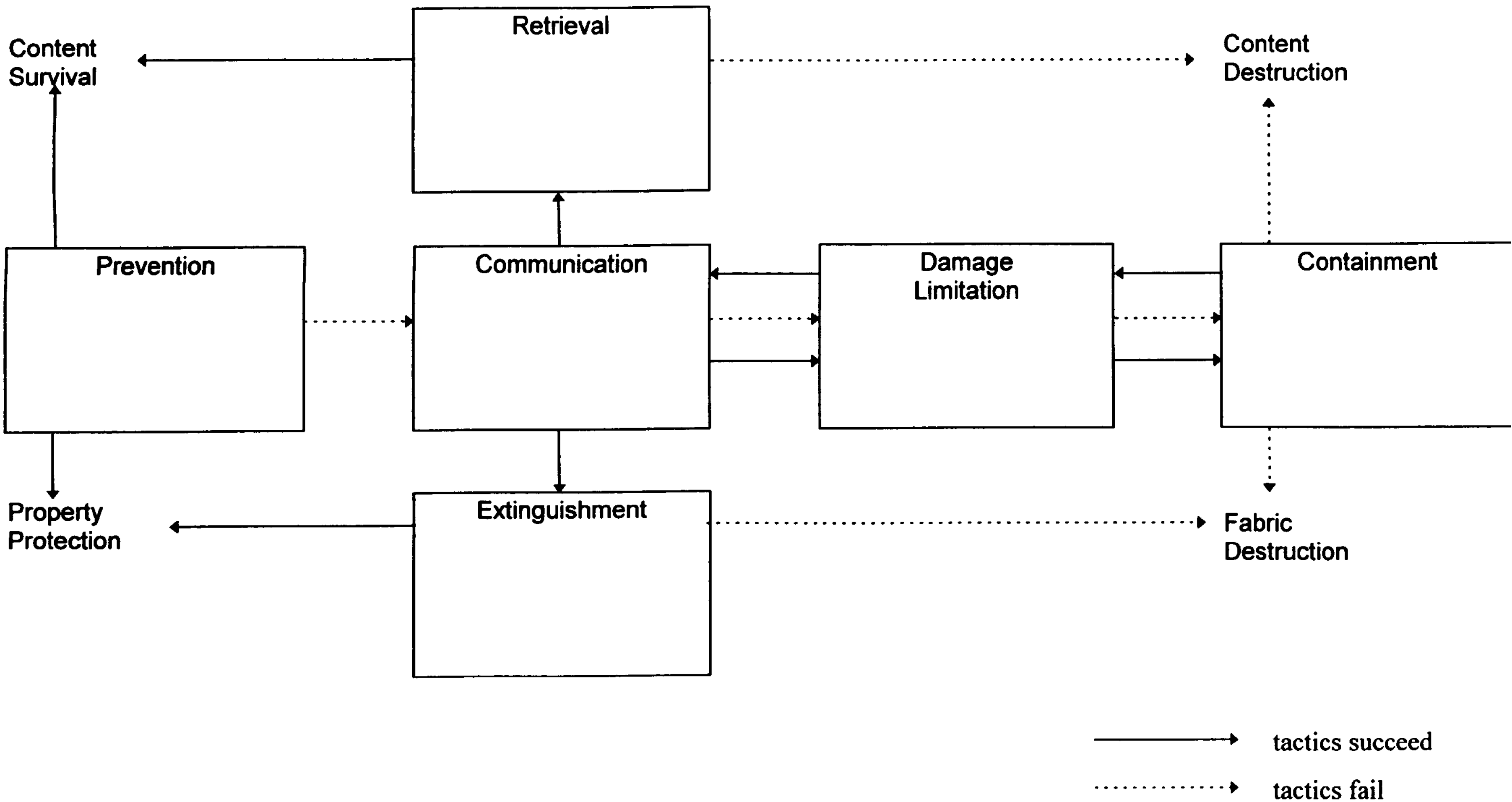
Objectives	Definition	Priority
Fabric preservation	To protect the historic fabric of the property from damage by fire and its associated dangers of heat, smoke and water	1
Contents protection	To protect the content of the property from damage by fire and its associated dangers of heat, smoke and water	2
Mission continuity	Maintenance of the property to provide a facility for acts of worship and other community functions with minimal disruption	3

8.3.3 Evaluation of the tactics

The Delphi group approved the five proposed tactics, but considered there to be a need to introduce a sixth tactic, damage limitation. It was felt that as the tactic of containment prevents fire spreading beyond the room of origin, there was need to have a tactic which limited fire spread within the enclosure of origin before the tactic of containment was confronted. The Delphi group gave the six tactics the priority ranking order, as shown in table 8.3.

The relation of the tactics and their contribution to fire safety can be clearly illustrated using a diagrammatic tactic to objective matrix. [see figure 8.3]. The tactics are presented in sequence. If prevention is successful then the other tactics are not required. However, it must be accepted that fire will occur at some point and so provision must be made for the remaining four tactics. Communication is the pivotal tactic. Its success or failure will

Figure 8.3: Tactic to objective interactions[27]



influence the effectiveness of extinguishment, damage limitation, containment and content retrieval. Failure of extinguishment, and/or containment will result in the destruction of the fabric. In addition, the failure of retrieval will result in contents destruction. This illustration along with the chart of intervention techniques [discussed in section 4.1.3, see table 4.16] aided the Delphi participants in effectively evaluating the suggested components of fire safety.

Table 8.3: The agreed tactics and their priority ranking

Tactics	Definition	Priority
Prevention	To prevent the initiation of destructive and uncontrolled burning	1
Communication	If ignition occurs the fire brigade and/or members of the public are quickly informed and active fire suppression systems are triggered	2
Extinguishment	The fire can be extinguished quickly and with minimum consequential damage to the building	3
Containment	To ensure that the fire is contained to the smallest possible area limiting the amount of the property likely to be damaged	4
Damage limitation[1]	The restriction of fire damage by the existence of fire limiting content and fabric	5
Retrieval	In the event of a fire, if it is safe to enter the building, valuable items of content can be retrieved from the property by a trained retrieval team	6

Note: [1] Additional tactic agreed by the Delphi group

8.3.4 Evaluation of the components

The Delphi participants were first asked to consider the relevance of the prepared list of components. This resulted in the group adding two additional components; building services and spatial configuration. The Delphi group considered building services to be an essential element of fire safety which had not been included in any of the proposed components. Similarly, the group considered the geometry and 'specific perimeter' of the interior surface of churches to have an influence on fire safety. This had also not been previously included.

It was also felt that two component titles should be renamed to reflect more comprehensively their content. Escape routes and exits was retitled access routes and exits, and retrieval training, retrieval training and practice.

Table 8.4: The agreed components

Component	Definition
Access routes & exits[i]	The provision of suitable alternative access and exit routes from the property to enable valuable items to be retrieved from enclosures
Building services[ii]	The structural elements of the property and their contribution to fire safety
Detection & communication	The capacity for the early discovery of fire and the alerting of the fire brigade and/or members of the passing public to take appropriate action
Emergency lighting	The provision of minimum illumination necessary to enable the retrieval team to move within and escape from the property in the event of the failure of normal lighting during a fire
Furniture & furnishings	The contribution of all hard and soft furniture and furnishings [mobile] to fire safety
Fixtures & fittings	The contribution of all hard and soft fixtures and fittings [immobile, excluding wooden wall panelling] to fire safety
Housekeeping[iii]	The organisation of storage areas and the management of cleaning activities
Interior finishes	All surface finishes on the interior of the building including wall panelling
Manual fire fighting equipment	First aid fire fighting appliances installed for the use of the occupants and/or the fire brigade
Management systems	The creation, implementation and periodic review of effective systems of fire safety
Passive protection	Fire resistant barriers to contain fire
Retrieval training and practice[i]	Training in the skill of valuable item retrieval in the event of fire
Security	Measures to prevent the unauthorised access of individuals into the property
Spatial configuration[ii]	The influence of the geometry of the building on the spread of fire and smoke
Suppression systems	A method of automatic suppression of fire
Smoke control	Factors which affect air movement in the building
The fire brigade	The fire fighting force provided by the local authority

Notes: [i] Change of title agreed by the Delphi group
[ii] Additional components agreed by the Delphi group
[iii] Change of definition agreed by the Delphi group

All component definitions were agreed, apart from that for housekeeping. The original definition: the organisation of storage areas, cleaning and maintenance activities, created confusion as Delphi participants believed it included building repair and maintenance [which was not the case]. The revised definition was agreed: the organisation of storage areas and the management of cleaning activities.

8.4 The matrix development

To score the inter-relationships, matrices were represented to the Delphi group this time asking the participants to indicate the absolute importance of the highlighted tactics to objective and components to tactics. The participants scored the degree of importance on a zero = no importance to ten = extremely important scale.

To establish the relative contribution of the eighteen components to the overall policy, the three matrices [as described in chapter seven] were multiplied in stages. The approach taken followed that used in the Edinburgh hospital scheme[28].

8.4.1 Unadjusted results

The unadjusted results from the Delphi group are shown below. Tables 8.5, 8.6 & 8.7 shows the contributory values. [The figures are the average of the seven Delphi participant responses shown as absolute contributions].

Table 8.5: Contributory values of objectives to policy

Fabric preservation	0.90
Content protection	0.71
Mission continuity	0.48

Table 8.6: Contributory values of tactics to objectives

	Fabric preservation	Content protection	Mission continuity
Prevention	0.92	0.99	0.79
Communication	0.80	0.80	0.66
Extinguishment	0.76	0.71	0.59
Containment	0.64	0.60	0.59
Damage limitation	0.66	0.71	0.49
Retrieval	0.00	0.67	0.49

Table 8.7: Contributory value of components to tactics

	1.	2.	3.	4.	5.	6.
Access routes & exits (1)	0.00	0.00	0.20	0.04	0.00	0.70
Building services (2)	0.73	0.04	0.07	0.27	0.26	0.13
Building structure (3)	0.24	0.00	0.00	0.83	0.14	0.11
Detection & comm. (4)	0.10	0.84	0.34	0.19	0.33	0.36
Emergency lighting (5)	0.00	0.00	0.27	0.00	0.00	0.69
Furniture & furnishings (6)	0.26	0.00	0.26	0.00	0.67	0.31
Fixtures & fittings (7)	0.53	0.00	0.14	0.00	0.69	0.20
Housekeeping (8)	0.77	0.03	0.36	0.00	0.57	0.41
Interior finishes (9)	0.53	0.00	0.13	0.00	0.66	0.16

Table 8.7: Contributory value of components to tactics [continued]

	1.	2.	3.	4.	5.	6.
Manual fire fight. equi.(10)	0.00	0.10	0.87	0.51	0.73	0.10
Management systems (11)	0.74	0.77	0.73	0.60	0.67	0.67
Passive protection (12)	0.06	0.00	0.00	0.80	0.67	0.19
Retrieval training & pr. (13)	0.00	0.07	0.00	0.00	0.69	0.99
Spatial configuration (14)	0.00	0.09	0.00	0.00	0.29	0.00
Security (15)	0.79	0.11	0.00	0.00	0.17	0.24
Suppression systems (16)	0.11	0.00	0.86	0.77	0.76	0.20
Smoke control (17)	0.00	0.00	0.00	0.67	0.74	0.24
The fire brigade (18)	0.57	0.19	0.94	0.76	0.79	0.67

Key: 1. = Prevention; 2. = Communication; 3. = Extinguishment; 4. = Containment; 5. = Damage limitation; 6. = Retrieval

The contributory value matrices are shown below. Vector two presents the absolute contribution of the components to the policy.

Table 8.8: Matrix multiplication of relative contribution matrices

	Objectives		Policy		Vector 1 [V1]
Tactics	6x3 Table 8.6	x Obj.	3x1 Table 8.5	=	see below

Vector 1 [V1]

Tactics*	Policy
1.	1.9030
2.	1.6048
3.	1.4713
4.	1.2852
5.	1.3333
6.	0.7109

	Tactics		Policy		Vector 2 [V2]
Components	18x6 Table 8.7	x Tac.	6x1 V1	=	see below

Vector 2 [V2]

Components*	Policy
1.	0.843298
2.	2.342452
3.	1.788297
4.	2.978675
5.	0.887772
6.	1.991008
7.	2.276729
8.	3.094572
9.	2.193581
10.	3.140362
11.	5.858699
12.	2.170722
13.	1.736104
14.	0.531089
15.	2.077175
16.	3.619740
17.	2.018342
18.	5.279006

Note: * see table 8.7

A review of the spread of the results, however, revealed some large variances between some of the participants' considered contributions. Concern was raised that such maverick results [results which laid outside a five point range] could skew the mean. Two options were considered:

- To re-present the questions to the Delphi group;
- To remove the maverick results from the evaluation.

The latter option was chosen and proved to be effective. The five point range [50% of the scale] was set as a cut-off inside which all the scores must lie. This produced the following results.

Table 8.9: Adjustment of scores: All scores sit in a five point range

	Objectives to policy	Tactics to objective	Components to tactics
Score OK	1	9	58
Score OK with one score excluded	2	6	32
Scores OK with two scores excluded	0	3	14
Scores do not fit	0	0	4
Totals	**3**	**18**	**108**

Only four component to tactic contributions remained diverse; detection and communication to damage limitation, furniture and furnishings to retrieval, fixtures and fittings to prevention and manual fire fighting to containment. It was decided to use the unadjusted means in these four cases.

8.4.2 Adjusted results

The calculation process as defined in section 8.4.1 was repeated using the adjusted results to assess the variation in the final component contributions.

Table 8.10: Contributory values of objectives to policy [adjusted results]

Fabric preservation	0.90
Content protection	0.78
Mission continuity	0.40

Table 8.11: Contributory values of tactics to objectives [adjusted results]

	Fabric preservation	Content protection	Mission continuity
Prevention	0.92	0.98	0.79
Communication	0.80	0.80	0.70
Extinguishment	0.76	0.73	0.59
Containment	0.72	0.73	0.59
Damage limitation	0.66	0.72	0.53
Retrieval	0.00	0.72	0.56

Table 8.12: Contributory value of components to tactics [adjusted results]

	1.	2.	3.	4.	5.	6.
Access routes & exits (1)	0.00	0.00	0.13	0.04	0.00	0.70
Building services (2)	0.68	0.04	0.07	0.18	0.26	0.66
Building structure (3)	0.20	0.00	0.00	0.83	0.05	0.00
Detection & comm. (4)	0.10	0.84	0.20	0.13	0.33	0.46
Emergency lighting (5)	0.00	0.00	0.22	0.00	0.00	0.63
Furniture & furnishings (6)	0.26	0.00	0.17	0.00	0.83	0.31
Fixtures & fittings (7)	0.53	0.00	0.14	0.00	0.78	0.08
Housekeeping (8)	0.90	0.03	0.30	0.00	0.57	0.42
Interior finishes (9)	0.48	0.00	0.13	0.00	0.62	0.00
Manual fire fight. equi.(10)	0.00	0.03	0.87	0.51	0.62	0.10
Management systems (11)	0.70	0.77	0.78	0.60	0.67	0.67
Passive protection (12)	0.06	0.00	0.00	0.88	0.62	0.10
Retrieval training & pr. (13)	0.00	0.07	0.00	0.00	0.82	0.99
Spatial configuration (14)	0.79	0.02	0.00	0.00	0.14	0.10
Security (15)	0.00	0.11	0.00	0.00	0.06	0.17
Suppression systems (16)	0.00	0.00	0.86	0.82	0.82	0.00
Smoke control (17)	0.00	0.00	0.00	0.67	0.74	0.18
The fire brigade (18)	0.60	0.02	0.94	0.74	0.85	0.68

Key: 1. = Prevention 2. = Communication 3. = Extinguishment
4. = Containment 5. = Damage limitation 6. = Retrieval

Similarly the matrix multiplication of the absolute contributions was conducted as detailed in table 8.13.

Table 8.13: Matrix multiplication of relative contribution matrices [adjusted results]

	Objectives		Policy	
Tactics	6x3 Table 8.11	x Obj.	3x1 Table 8.10	=

Vector 1 [V1]

Tactics*	Policy
1.	1.9084
2.	1.6240
3.	1.4498
4.	1.4534
5.	1.3676
6.	0.7856

	Tactics		Policy	
Components	18x6 Table 8.12	x Tac.	6x1 V1	=

Vector 2 [V2]

Components*	Policy
1.	0.796530
2.	2.599842
3.	1.656382
4.	2.846586
5.	0.813884
6.	2.121294
7.	2.344000
8.	3.310704
9.	1.952418
10.	2.977752
11.	6.031888
12.	2.319968
13.	2.012856
14.	0.223944
15.	1.901884
16.	3.560048
17.	2.127210
18.	5.312516

Note: * see table 8.12

8.4.2.1 Discussion of the results

The calculated percentage contribution of each component to the overall policy is shown in table 8.14. Firstly, if the unadjusted and adjusted relative component contributions are compared it can be seen that the percentage contributions vary by +/- 1% on six of the components. All six of those components, however, sit in the 4% to 6% contribution range. These results clearly show that the adjustments do not effect those components which reside at the extremes of the range. A strong consensus amongst the Delphi participants to support those components can be noted.

The component contribution range can be seen to extend from 1% to 13%. The components of management systems [13%] and the fire brigade [12%] having a considerably larger contributions than the other components. As a counter evaluation an additional measure of the considered importance of the components to fire safety was

Table 8.14: Relative values of the unadjusted and adjusted component contributions to fire safety

Components	**Relative contributions: using unadjusted results**		**Relative contribution: using adjusted results [up to two maverick results excluded, so all scores sit in a five point range]**	
	Overall contribution	Ranking	Overall contribution	Ranking
Access routes & exits	0.018812 [2%]	17	0.017736 [2%]	17
Building services	0.052255 [5%]	7	0.057890 [6%] (+1)	7
Building structure	0.039893 [4%]	14	0.036882 [4%]	15
Detection & communication	0.066447 [7%]	6	0.063385 [6%] (-1)	6
Emergency lighting	0.019804 [2%]	16	0.018123 [2%]	16
Furniture & furnishings	0.044415 [4%]	13	0.047235 [5%] (+1)	11
Fixtures & fittings	0.050789 [5%]	8	0.052194 [5%]	8
Housekeeping	0.069033 [7%]	5	0.073719 [7%]	4
Interior finishes	0.048934 [5%]	9	0.043474 [4%] (-1)	13
Manual fire fighting equip.	0.070054 [7%]	4	0.066305 [7%]	5
Management systems	0.130694 [13%]	1	0.134311 [13%]	1
Passive protection	0.048424 [5%]	10	0.051658 [5%]	9
Retrieval training & practice	0.038728 [4%]	15	0.044820 [4%]	12
Spatial configuration	0.011847 [1%]	18	0.004987 [1%]	18
Security	0.046337 [5%]	11	0.042349 [4%] (-1)	14
Suppression systems	0.080748 [8%]	3	0.079271 [8%]	3
Smoke control	0.045025 [4%]	12	0.047366 [5%] (+1)	10
Fire brigade	0.117762 [12%]	2	0.118293 [12%]	2

conducted. The Delphi group was asked to simply rank the components in importance priority order. Table 8.15 shows the priority ranking and set along side the ranking as determined from the outcome of the matrix multiplications.

Table 8.15 : Priority ranking comparison

Grouping-from initial ranking[i]	**Grouping-from relative contributions**[ii]**[adjusted res.]**
Components	*Components*
Group A: high importance	**Group A: high contribution**
Detection and communication	Management systems
Security	The fire brigade
The fire brigade	
Management systems	
Group B: medium importance	**Group B: medium contribution**
Furniture and furnishings	Suppression systems
Fixtures and fittings	Detection and communication
Passive protection	Housekeeping
Manual fire fighting equipment	Manual fire fighting equipment
Interior finishes	Building services
Building services	Fixtures and fittings
Building structure	Passive protection
Smoke control	Furniture and furnishings
Housekeeping	Smoke control
Spatial configuration	
Group C: low importance	**Group C: low contribution**
Escape routes and exits	Security
Emergency lighting	Retrieval training
Suppression systems	Interior finishes
Retrieval training	Building structure
	Emergency lighting
	Escape routes and exits
	Spatial configuration

Notes: [i] group A = av. ranking 1-6, group B = av. ranking 7-12, group C = av. ranking 13-18
[ii] group A = cont. >8%, group B = cont. 5-8%, group C = cont. 0-4%,

It can be seen that in respect to the two largest component contributors [management systems and the fire brigade] their positions are supported by the priority ranking list. Eight of the eighteen components show a large difference in their ranking position. The component of security is most extreme. It is identified as being a very important aspect but in fact its contribution is made largely to one tactic and so the overall contribution is relatively small. Building structure, interior finishes, furniture and furnishings and spatial configuration are also in the same situation but to a lesser extreme. Working in the opposite way is suppression systems which moves from seventeenth to third. This may be due to the fact that suppression systems are very rare in churches at present and so their contribution is assumed to be limited, but in reality if deployed, they make a broad contribution to the tactics. Housekeeping and retrieval training and practice also move up in ranking position but again to a lesser extent.

These variations in ranking order illustrate how hierarchical interactions influence initial expert opinion. When the Delphi participants undertook the simple importance priority ranking, no consideration was given to the value of diverse contributions [contribute to a number of tactics] of components as opposed to specialist contribution [contribute largely to just one tactic]. The hierarchical interactions enabled such considerations to take place but the results still suggest that the complexity of understanding diverse and specialist contributions may be the reason for the diversity in Delphi participant opinion. This is illustrated by the fact that four of the six components which have been adjusted by +/-1% are those which rank very differently in the two listings. Those components being security, housekeeping, furniture and furnishings, interior finishes and detection and communication.

8.4.3 Components to components analysis

This analysis has established the relative contribution of the eighteen components to the overall policy by evaluating the inter-relationships between the components to tactics and tactics to objectives. This analysis, however, has not considered the inter-relationships between individual components. Such a manipulation involves the considered interactions of pairs of components and whether such interactions are an enhancement to the two components concerned. A matrix expressing these interactions can be used to modify the component vector to give a new set of values [see table 8.17].

The development of a suitable procedure to enable the knowledge of the Delphi group to be gained was extremely complex. After careful consideration it was decided not to ask the Delphi group to consider the interactions between individual components for the following reasons:

- As shown in previous studies[29] it makes very little difference to the overall components contributions.
- It was considered not worth the intellectual effort for such little benefit gained.

Table 8.16: Component to component interactions

com.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1		0.7	0.3	0.3	0.3		0.1	0.3	0.2		0.5	0.1		0.1		0.2	0.2	0.3
2	0.4		0.3	0.1	0.5		0.4	0.1	0.2			0.5	0.4	0.6	0.6	0.6	0.6	0.7
3				0.1	0.2						0.8	0.2	0.3		0.6	0.7	0.5	0.8
4					0.8					0.3	0.3		0.7		0.2			0.4
5			0.1							0.2			0.7					0.3
6								0.4					0.4					
7	0.2		0.2		0.1			0.3	0.6			0.6	0.1	0.5	0.1		0.1	0.2
8	0.3				0.5	0.6	0.6		0.2	0.2	0.6		0.5		0.3			0.3
9			0.3	0.3			2.0					0.7						
10	0.4					0.2	0.2				0.5		0.5					0.3
11	0.3		0.6	0.4	0.4	0.5	0.3	0.5		0.7			0.5		0.7			0.3
12		0.3			0.3		0.3		0.3					0.2				0.2
13								0.2			0.6				0.2			0.4
14	0.2	0.2	0.6	0.1	0.2		0.1						0.4		0.1	0.6	0.5	0.2
15			0.1			0.3	0.2	0.5			0.6		0.2					0.4
16	0.2							0.2		0.5	0.3		0.2	0.2			0.3	0.5
17											0.2		0.2	0.2	0.1	0.2		0.6
18		0.1	0.5	0.2	0.2			0.2		0.4	0.5		0.6		0.2	0.4	0.7	

Components:
1. Building services
2. Building structure
3. Detection & communication
4. Emergency lighting
5. Access routes & exists
6. Furniture & furnishings
7. Fixtures & fittings
8. Housekeeping
9. Interior finishes
10. Manual fire fighting equip.
11. Management systems
12. Passive protection
13. Retrieval training
14. Spatial configuration
15. Security
16. Suppression systems
17. Smoke control
18. Fire brigade

Table 8.17: The effect of including component to component interactions on the component contributory values

	V2	Man. no3	V3	V2[n]	V3[n]	V2%	V3%	V2% [rou.]	V3% [rou.]	Diff. %
Access ro. & ex.	0.79653	0.136	0.93253	0.017736	0.017692	1.78	1.77	2	2	0.01
Building services	2.599842	0.485	3.084842	0.057890	0.058527	5.79	5.85	6	6	-0.06
Building structure	1.656382	0.659	2.315382	0.036882	0.043929	3.69	4.39	4	4	-0.7
Det. & comm.	2.846586	0.715	3.561586	0.063385	0.067572	6.34	6.76	6	7(+1)	-0.42
Emergency light.	0.813884	0.262	1.075884	0.018123	0.020412	1.81	2.04	2	2	-0.23
Fur. & furnish.	2.121294	0.106	2.227294	0.047235	0.042257	4.72	4.22	5	4(-1)	0.5
Fix. & fittings	2.344000	0.333	2.677000	0.052194	0.05079	5.22	5.08	5	5	0.14
Housekeeping	3.310704	0.699	4.009704	0.073719	0.076074	7.37	7.61	7	8(+1)	-0.24
Interior finishes	1.952418	0.169	2.121418	0.043474	0.040249	4.35	4.02	4	4	0.33
Man. f. f. equp.	2.977752	0.383	3.360752	0.066305	0.063762	6.63	6.38	7	6(-1)	0.25
Man. systems	6.031888	1.219	7.250888	0.134311	0.137568	13.43	13.76	13	14(+1)	-0.33
Pass. protection	2.319968	0.189	2.508968	0.051658	0.047602	5.17	4.76	5	5	0.41
Ret. training	2.012856	0.266	2.278856	0.044820	0.043236	4.48	4.32	4	4	0.16
Spat. conf.	0.223944	0.242	0.465944	0.004987	0.00884	0.49	0.88	1	1	-0.39
Security	1.901884	0.376	2.277884	0.042349	0.043217	4.23	4.32	4	4	-0.09
Supp. systems	3.560048	0.465	4.025048	0.079271	0.076365	7.93	7.63	8	8	0.3
Smoke control	2.127210	0.247	2.37421	0.047366	0.045045	4.74	4.5	5	4(-1)	0.24
Fire brigade	5.312516	0.847	6.159516	0.118293	0.116862	11.83	11.68	12	12	0.15

Where: V2 = vector 2 [table 8.13]
Man. no3 = vector manipulation [equation page 209]
V3 = vector 3 [V2 + man. no3]
V2 [n] and V3 [n] = normalised results
V2% and V3% = scores presented as percentages
V2 [r] and V3 [r] = scores rounded to whole numbers
Diff. % = difference between V2% and V3%

To demonstrate the potential effect of the component to component interactions, the author carried out the assessment using personal judgement [see table 8.16]. The results have been manipulated using the following equation as recommended by the Edinburgh hospital scheme[30] [manipulation 3].

$$V3(N) = \frac{\sum_{L=1}^{18} \frac{[V2(N) + V2(L)]_{iL}}{2}}{18} + V2(N)$$

Where

i = interaction
V = vector
N = number
L = components

It can be seen that from table 8.17 that the inclusion of the component to component interactions produces an average variation of +/- 0.275% to the overall component contributions. Six components are adjusted by +/- 1%. A full scale exercise is likely to produce variances of the same magnitude. A decision was taken not to conduct the exercise and not to further adjust the component contributions to fire safety.

8.4.5 Finalised component contributions

The overall component contributions to be used in the procedure are shown in table 8.18. These were represented to the Delphi participants for their approval after the Delphi sessions.

While it is not possible, or desirable to directly compare the component contributions to existing fire safety evaluation schemes, as the objectives of the procedures and definitions of the components are different in each case, a broad comparison is beneficial. Appendix G3 shows the component contributions of three existing fire safety schemes. A review shows that only a management component has a consistently high contribution in all case, while no further similarities exist.

Table 8.18: Finalised component contributions

Components	% contribution
Management systems	13
Fire brigade	12
Suppression systems	8
Housekeeping	7
Manual fire fighting equipment	7
Building services	6
Detection & communication	6
Furniture & furnishings	5
Fixtures & fittings	5
Passive protection	5
Smoke control	5
Building structure	4
Interior finishes	4
Retrieval training & practice	4
Security	4
Access route & exits	2
Emergency lighting	2
Spatial configuration	1

8.5 Creation of the component worksheets

With the components established, the survey and assessment approaches were developed. For each component, a worksheet was created which as a collection formed the framework and content of the fire safety survey. Their development is explained in this section.

8.5.1 Worksheet development

The component worksheet's development underwent a stepped evolutionary process:

Step 1: Crude arrangement of sub-components under proposed components [draft 1, see appendix G4]

Step 2. Alignment of requirements with the 'collated norm' [draft 2]

Step 3: Creation of a user friendly survey interface [drafts 3 to 5] [draft 5 see appendix G5]

The final agreed eighteen components cover the principle areas of fire safety in parish churches. [and correspond to the intervention techniques as discussed in chapter four]. Each component initially entailed a suggested list of sub-components which were considered to form an element of the component. [some sub-components appeared under more than one component initially. See draft 1, appendix G4]. Next, the relevant elements of the 'collated norm' were placed alongside each relevant sub-component. The abstracted statement from the 'collated norm' represented the 'perfect contribution' [see glossary of definition] to fire safety for each sub-component. After that initial exercise, the exact sub-components of each component were confirmed and the overall 'perfect contribution' for each component was agreed.

The worksheets were then translated into an effective style to act as a survey document. Creating a survey approach, however, which would strike the right balance between being too complex and too crude, proved extremely problematic. The principle problems were:

1. Detailing the selected aspects of the 'collated norm' in a concise manner, so that reference could be made during the assessment;
2. Creating a concise survey format that would handle all the required assessment elements;
3. Finding an effective scoring structure;
4. Creating a survey approach which could effectively handle the assessment of a complete building and not just one enclosure.

Five drafts were developed and commented upon. The fifth draft was used in the developmental and repeatability trials [as shown in appendix G5 and detailed in chapter nine]. The detailed problems were overcome as outlined below:

Problem 1: The key elements only, of the 'collated norm' documents were included in the worksheet pro-forma. At this prototype stage it proved adequate, but it is anticipated that an accompanying survey manual would be written for further testing.

Problem 2: It was emphasised to the assessors that to aid the assessment of individual sub-component contributions, the pro-forma should be used as a guide only, to create an overall judgement. Each small aspect of the assessment should not be deliberated over as the assessment is an overall judgement.

Problem 3: Two scoring scales were considered: a scale of zero to ten and a scale of zero to five. The latter was chosen because the nature of the judgement assessment did not warrant a finer scale.

Problem 4: To accommodate the need to complete a fire safety assessment of the complete building, components were divided into those which assessed an 'observable space' [see glossary for definition] and those which assessed the complete building as one item. See table 8.19.

Table 8.19: Component worksheet assessment basis

Assessment on a observable space basis	**Assessment on a complete building basis**
Spatial configuration	Building structure
Access routes and exits	Furniture and furnishings
Passive protection	Fittings and fixtures
Interior finishes	Security
Emergency lighting	The fire brigade
Smoke control	Suppression systems
	Manual fire fighting equipment
	Detection and communication
	Building services
	Housekeeping
	Retrieval training and practice
	Management systems

8.5.2 Layout of the worksheets

The worksheets are designed to guide the assessor to an accurate assessment of the safety contribution of each component. [The required knowledge level of the assessor is not considered in this chapter, but evaluated in sections 9.2, 9.3 and 9.7.2]. As shown in figure 8.4 a series of aid-memoirs are presented for each component which help the assessor consider all the necessary sub-components before making the survey score. [Note that no differentiation is made in this survey between an assessment of risk and safety. All factors considered to contribute to fire safety are taken to contribute in a positive or negative manner to an overall assessment of fire safety] [Section 5.3 identifies the rational to this approach].

The scoring for each component, is at this stage, very much left to the judgement and expertise of the assessor. In each component's case, the scoring range and criteria is laid out and it is the assessor's responsibility to weigh up the evidence gathered by completing the aid-memoir carefully, before selecting a score. [it is anticipated that the scoring approach will be refined at a 'second cut' stage [see glossary for definition]]. For those components that are assessed on an 'observable space' basis, the total building score is calculated in section 8.5.4.

Figure 8.4: Example of the layout of a component worksheet

Component: **Detection and Communication**

Survey score	
Church:	
Score:	0 1 2 3 4 5

Definition: The capacity for the early discovery of the fire and the alerting of the fire brigade and/or members of the passing public to take appropriate action.

Specification reference(s): EIG Guidance note 1, BS5839 Part 1: Fire Detection and Alarm Systems in Buildings, BS5979: Code of Practice for Remote Centres of Alarm Systems

Consideration: Complete the following checklist

	Yes	No
Automatic detection and alarm • Does the church have a detection and alarm system which qualifies for an EIG fire alarm discount? *Specification: The entire building must be protected by an automatic fire detection and alarm system installed to BS 5839 Part 1. To include remote signalling conforming to BS5979. There must also be a annual maintenance contract*		
Church location • Is the church overlooked by the vicarage or other occupied building(s)? • Can the church be clearly seen from a public road? • Is there a public phone within 500m of the church?		
Church surveillance • On average, how often is the church visited/used? Daily At least 4 days per week Less than 4 days per week		

Assessment: Make an initial assessment of the adequacy of the detection and communication facility available based on the quality of the detection and alarm system present. Where 5 is a completely perfect system which qualifies for a EIG discount and 3 is a system which fails to achieve the requirement of an EIG discount. If no detection and alarm system is present then a maximum of 3 can be scored. 3 being where the churches surveillance and location is good and 0 where the churches surveillance and location is poor. Mark the score in the survey box at the top of the worksheet.

Survey type: Visual | Desktop   Assessment basis: Complete building

8.5.3 Conducting the worksheet survey

Further to creating the component worksheets a guide to conducting the survey was also developed. The following steps to conducting the survey are recommended:

- Read through the survey document before arriving at the church and gain an understanding of the assessment approach and the history of the building.
- When at the church take a walk around the outside and note all relevant issues [just generally at this stage].
- When inside the church again walk around all the observable spaces to get a 'feel' for the building and its level of fire safety.
- Then it is suggested that the components are addressed in the following groups [as shown in table 8.20]. They have been arranged so that similar aspects of fire safety are dealt with together.

Table 8.20: Suggested group assessment of components

Group 1:Shape size and construction of the church
Spatial configuration
Building structure
Access routes and exits
Group 2:Degree of resistance to spread of fire
Passive protection
Interior finishes
Furniture and furnishings
Fittings and fixtures
Group 3:Provision of active fire and security precautions
Security
The fire brigade
Suppression systems
Manual fire fighting equipment
Detection and communication
Emergency lighting
Smoke control
Group 4:Building facilities and management issues
Building services
Housekeeping
Retrieval training and practice
Management systems

- It is suggested that the assessment of components in group 1 are completed throughout the whole building before starting the group 2 components etc.
- Complete the assessment for each component before leaving the building.

To carry out the survey the assessor needs only a clipboard and a 3m pocket tape. The measurement of large horizontal detail should be pacing. Vertical dimension can be estimated. It is anticipated that the survey will take no more than two hours.

8.5.4 Scoring the survey

As previously stated, the assessor makes an on-site assessment of fire safety for each component, either on an 'observable space' or whole building basis. Four different scoring methods are used to assess the components: [see appendix G6 for details of individual components scoring method]

1. The assigning of an approximate score to the dominant sub-component and then modifying that depending upon the assessors evaluation of the remaining sub-components.
2. The simple addition of values awarded to relevant sub-components.
3. The comparison of the condition in an 'observable space' with details on the worksheet from which the appropriate score can allocated.
4. The direct comparison of each sub-component within a component with an established measure of 'perfect contribution' [see glossary for definition] derived from the 'collated norm'.

For fifteen of the components the score scale ranges from a score of five representing a component providing a 'perfect contribution' to fire safety [assessed against the 'collated norm'] and a score of zero indicating a totally inadequate or non-existent component contribution to fire safety. For three components, however, an assessment of a 'perfect contribution' is not appropriate. For the building services component the level of service provision is assessed around an 'acceptable contribution' [a score of three, see glossary for definition]. Scoring is then made above or below the 'acceptable contribution' so a maximum or minimum score can be recorded. Similarly, with the components, furniture and furnishings and fittings and fixtures an assessment is made around a 'typical contribution' [again a score of three, see glossary for definition]. It is technically possible to score five on each component, which when multiplied by the percentage contribution of each component, gives a maximum total fire safety score of 500. In practice, however, this situation is not realistically possible, so a 'maximum attainable' score has been calculated. [see glossary for definition and appendix H4 for a detailed explanation].

For six components, [see table 8.19] individual 'observable spaces' scores are required to be converted into an overall building score. In the case of the Edinburgh hospital scheme[31], the number of bed spaces in a ward was used as a multiplying factor. Two approaches were considered suitable in this case:

1. An average of the 'observable space' scores to represent a whole building score. Using the following equation:

$$WBS = \sum_{i}^{n} \left(\frac{(obsp)_i}{n} \right)$$

2. An area multiplication factor on each 'observable space' to generate a whole building score. Using the following equation:

$$WBS = \sum_{i}^{n} \left(\frac{(obsp)_i \times a_i}{\sum_i a_i} \right)$$

Where

i	= number of 'observable spaces'
$(obsp)_i$	= score of 'observable space' i
a_i	= area for 'observable space' i
WBS	= whole building score

An example of the score variance using both methods is shown in table 8.21. Both of these approaches to scoring are further explored in chapter nine.

Table 8.21: Calculating a component whole building score using the area multiplier and simple average approaches

Church: St Mary de Castro, Leicester **Component: Access and exit routes**		
Observable space	**Score**	**Area [m^2]**
Main worship area	4	750
South porch	4	6
Boiler room	5	4
Tower 1st floor	2	16
Tower 2nd floor	1	16
Sacristy	4	9
Overall score taken as a simple average: 4 + 4 + 5 + 2 + 1 + 4 = 20 / 6 = **3.3**		
Overall score using the area multiplier: [4 x 750] + [4 x 6] + [5 x 4] + [2 x 16] + [1 x 16] + [4 x 9] -- 750 + 6 + 4 + 16 + 16+ 9 = **3.9**		

8.6 Vulnerability assessment

As laid out in chapter seven, the fire safety evaluation procedure for the property protection of parish churches consists of two sections. An evaluation of fire safety and an evaluation of vulnerability. As for the fire safety hierarchy, the 'expert' knowledge of the participants in the Delphi group was used to develop the composition of an effective assessment of vulnerability. Discussion initially took place to define vulnerability used in this context and to consider the potential variables of an assessment of vulnerability and their inter-relationships. Figure 7.6 illustrates the outcome of this discussion.

Agreement was reached that the two key variables in an assessment of vulnerability is the quality of the building [the building's worth] and the maximum likely loss from a fire [the degree of loss] [the inter-relationships of these variables are detailed in chapter seven]. The Delphi group was asked to consider how these two variables could be assessed. Evidence to support the approaches taken are detailed below.

8.6.1 Building worth assessment

As identified in chapter two, building worth broadly consists of four criteria: cultural, functional, monetary and town/villagescape value. The structured assessment of the criteria has been shown to be problematic due to the considerable subjectivity involved. In an attempt to control this problem, a decision was taken to consider only the two principal criteria, judged by the Delphi group, as shown in table 8.22.

Table 8.22: Ranking in order of importance to building worth

Criteria	Priority	Contribution on a scale 0 - 10
Cultural value	1	8.8
Functional value	2	8.1
Monetary value	3	5.7
Town/villagescape value	4	4.8

Note: Contribution is the average of the seven Delphi participants

It was agreed that the statutory listing grades should be used as an assessment of cultural value. To provide a value for each grading, to be used within the procedure, the Delphi participants were asked to grade the cultural value of grade II*, II and not listed churches, on a scale of zero to ten [given that a grade I church scores ten]. The response is shown in table 8.23.

Table 8.23: Considered cultural value of listed churches compared to grade I listing

Listing	Value on a scale 0 -10
Grade II*	8.1
Grade II	6.1
Not listed	3.8

Note: Contribution is the average of the seven Delphi participants

Given this data, the following normalised weighting values are allocated to each statutory listing grade: grade I: 1.0, grade II*: 0.75, grade II: 0.5, not listed: 0.25.

Various approaches to the assessment of functional value were explored and presented to the Delphi group. The response is shown in table 8.24.

Table 8.24: Functional value assessment approaches

Functional value assessment ideas	Considered effectiveness on a scale of 0 - 5
Average number of hours the church is used each week	4.1
Average attendance/population of the parish	3.8
Average attendance/seating capacity	2.7
Average attendance/number of people on the churches electoral role	2.5
Number of people signing the visitors book in a given period	2.4

Note: Contribution is the average of the seven Delphi participants

The Delphi group suggested that the average number of hours the church is open per week presents the most effective assessment of functional use. However, such data is not readily available. Similarly, the same situation is true for the second favoured option. For the sake of the prototype evaluation procedure the third option is used as the data is readily available. The seating capacity for each church is taken from the diocesan directory and the average attendance is the number submitted by each parish to the Church of England yearly for funding provisions. A record is held by the incumbent and the diocese.

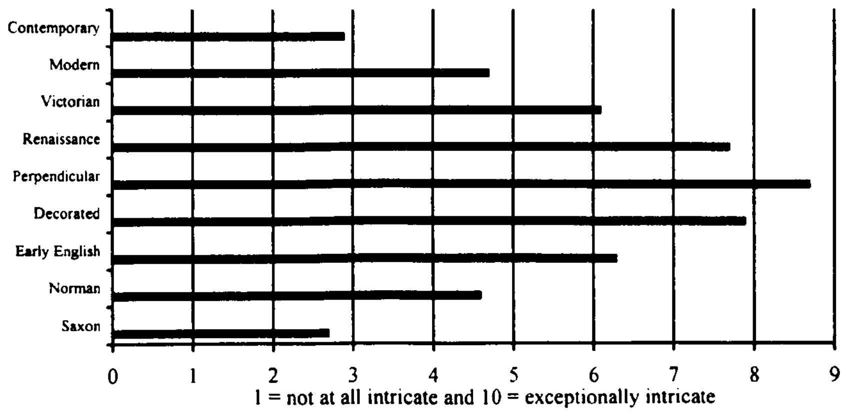
8.6.2 Degree of loss from fire

Two issues relating to the degree of loss from fire were presented to the Delphi group. Firstly, it was proposed that the surface area of the fabric and content ['specific perimeter' of detail] is dictated by the intricacy of the architectural style. An increase in the surface area of fabric and content will increase the vulnerability of churches to fire in two ways:

- For combustible materials, it presents a greater surface area to burn.
- For non-combustible materials, the damage by smoke and water will be more severe.

The 'specific perimeter' of ecclesiastical architectural styles was suggested by the Delphi group to be represented as follows:

Figure 8.5: Level of intricacy displayed in ecclesiastical architectural styles



This scaled intricacy profile is used in the assessment of the spatial configuration component worksheet [see appendix G5].

Finally, the Delphi group confirmed the assumption made concerning the likely maximum loss: that a potential maximum loss can be taken as the area of the enclosure of the fire origin [discussed in section 7.3.4], so a maximum loss is the area of the largest enclosure in the church building. The assumption is supported by data showing 85% of fires in places of worship were contained to the room of origin [table 4.12].

8.7 Summary

In this chapter the Delphi approach to knowledge acquisition has been discussed and applied. As a consensus tool the technique has been shown to have potential methodological problems, however, it is considered that if used with knowledge and skill and with a correct understanding of its application and limitations it can be an effective technique. The enquiry in question does not lend itself to precise analytical techniques, but does benefit from subjective judgement on a collective basis.

A Delphi group of seven participants was assembled and two face-to-face Delphi sessions were conducted. The participants were consulted on a range of issues relating to the development of the fire safety evaluation procedure through the completion of a series of questionnaires. The face-to-face approach was particularly helpful to clarify issues and to discuss other relevant subjects not included in the Delphi questionnaires. Independent thinking was still maintained by the effective management of the sessions. No communication was allowed during the completion of the questionnaires.

The classifications and weightings for the various elements of the fire safety hierarchy was generated from the output of the Delphi group sessions. The finalised component contributions to the overall policy show that management systems [13%] and the fire brigade [12%] are considered by the Delphi group to have the largest contribution to fire safety for the property protection of parish churches, while spatial configuration has the least [1%]. The high management contribution is reflected in other 'unique occupancy' evaluation schemes. The study has shown that the matrix multiplications reward those components which have a moderate, but diverse contribution to tactics rather than those that make a large specialist contribution. The priority ranking comparison table [8.14] shows this to be most extreme in the cases of the components of security and suppression systems. A trial component to component analysis has demonstrated that such an analysis makes very little difference to the overall component contributions and thus was not presented to the Delphi group.

The fire safety survey is shown to consist of eighteen component worksheets. Each contains a series of aid-memoirs which guide the assessor in considering all the necessary sub-components before making the component assessment. Each assessment is made against a standard contained in the 'collated norm'.

Each component is scored between five and zero. Where five represents a 'perfect contribution' to fire safety and zero represents a totally inadequate or non-existent contribution to fire safety. Twelve components are scored on a whole buildings basis while six are score on an 'observable space' basis. An average multiplication and an area multiplication approach are demonstrated as methods for translating the 'observable space' scores to whole building scores. The component scores when multiplied by the component contribution percentages produce a total fire safety score for individual churches.

In addition, the Delphi group was consulted on the composition of an assessment for vulnerability. Agreement was reached that the two key variables in an assessment of vulnerability is the quality of the building [the building's worth] and the maximum likely loss from a fire [the degree of loss]. The Delphi group provided a consensus as to how these two variables could be assessed.

The operational mechanics of the fire safety evaluation procedure have now been detailed and the variable classification and weightings have been applied. The procedure [in a prototype form] can now be tested.

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CHAPTER NINE

APPLICATION OF THE PROTOTYPE EVALUATION PROCEDURE

9. APPLICATION OF THE PROTOTYPE EVALUATION PROCEDURE

9.0 Introduction

This chapter initially reports on a series of pilot tests undertaken on the prototype evaluation procedure. An analysis of the procedure is then undertaken. Verification, levels of acceptability and approaches to least-cost fire safety improvements are covered. The effectiveness of the development and application, within the limitations of the thesis is then assessed and problems and issues which lie ahead are addressed.

9.1 Scope of the application

Further to the development of the prototype fire safety evaluation procedure, this chapter presents the results of a series of initial application trials. At this embryonic stage, these pilot tests enable an appreciation of the effectiveness of the developed evaluation procedure to be gained. They were specifically undertaken to aid the further development and refinement of the procedure and to give a simple measure of its ultimate utility. The pilot tests evaluated firstly, the effectiveness of the 'first cut' survey worksheets and secondly, the success of the operational sequence of the overall evaluation procedure.

The sample used in the pilot tests is too small to benefit from a statistical analysis, but the outcomes are considered to have enough value to either support or disprove the posed hypothesis.

9.2 Test 1: Developmental surveys

St Mary De Castro Church, Castle View, Leicester was used as the test-bed for the developmental surveys. The church is a grade I listed building. It consists of medieval and nineteenth century construction.

9.2.1 The methodology

The aim of this exercise was to:

- Identify ambiguities and potential misunderstandings in the fire safety element of the evaluation procedure in general and in the worksheets specifically;
- Provide a feel for the repeatability of the developed procedure when used by an 'expert'.

Five 'experts' were selected to undertake the survey. These were individuals from the Delphi group who had a suitable knowledge of building technology, a broad appreciation of church architecture and construction methods and an understanding of fire safety issues and practices. In addition, the author also undertook the survey.

As the assessors were participants in the Delphi sessions they had an existing knowledge of the evaluation procedure. However, the component worksheets had not been previously viewed by the assessors. Each assessor received a five minute briefing before starting the survey, so they were familiar with how to carry out the assessment and the necessary approach in undertaking assessment judgements. Each assessor conducted the assessment separately so that their interpretations and judgements were not influenced by fellow assessors. Problems and concerns were recorded on a feedback sheet.

9.2.2 The results

The overall scores for each assessor are shown in table 9.1. [The maximum score is 500]

Table 9.1: Fire safety assessment scores [FSM] for St Mary De Castro Church

Assessor	Profession/expertise	Score
Delphi participates:		
1. Dr E Marchant	Fire engineer & architect	257
2. Mr T Bray	Fire prevention officer	219
3. Prof P Swallow	Historic building surveyor	237
4. Dr D Watt	Conservation officer	214
5. Dr A Lyons	Material scientist	235
Additional assessor:		
6. Mr A Copping	Building management	263
		Mean: 238
		Range: 49

Table 9.2: Individual component scores for the developmental survey assessment

Church	St Mary De Castro					
Assessors	1	2	3	4	5	6
Components						
Access routes and exits	1	2	2	2	3	3
Building services	4	2	3	3	3	2
Building structure	4	4	4	4	4	4
Detection and communication	2	2	2	2	2	3
Emergency lighting	1	0	2	2	2	1
Furniture and Furnishings	3	3	4	4	4	3
Fittings and fixtures	4	4	3	3	3	3
Housekeeping	4	3	4	4	4	4
Interior finishes	4	4	3	3	3	4
Manual fire fighting equipment	1	3	3	2	1	4
Management systems	2	0	2	1	2	2
Passive protection	4	4	3	2	3	4
Retrieval training and practice	1	1	1	1	1	1
Spatial configuration	4	4	3	2	3	4
Security	2	3	2	2	2	3
Smoke control	1	1	1	2	1	1
Suppression systems	0	0	0	0	0	0
The fire brigade	4	3	3	2	3	3
Total:	**42**	**42**	**45**	**41**	**43**	**49**
			Mean: 43.5	**Range: 8**		

Notes: The component scores are the average score for all 'observable spaces' [FSM Opt.1 see table 9.12]
Totals are the sum of the eighteen components and have not been modified to reflect the importance of the components

9.2.3 Discussion of results

The feedback from the assessors was carefully analysed. The key findings are summarised below. Reference to the survey guide and worksheets in appendix G5 may be beneficial.

9.2.3.1 Ambiguities and misunderstandings in the survey guide and worksheets

The assessors found a number of problems with the survey guide and worksheets. In addition to small typographic errors comments included the following as shown in table 9.3.

Table 9.3: Constructive criticisms of the 'first cut' survey guide and worksheets

Comments
• The worksheets contained too much written text, making the assessment appear complex
• The relationship between the full and half page worksheets was confusing
• Assessors were unclear as to the significance of the specification references
• The descriptions for the method of assessment were for some of the components considered to be over elaborate
• The method of bringing forward the scores to a summary page was not clearly described

9.2.3.2 Viability of the assessment approach

Similarly, comments were made by the 'experts' concerning problems encountered with the assessment approach in general. The key points are laid out in table 9.4.

Table 9.4: Problems identified concerning the assessment approach

Comments
• Following the questions laid out in each aid-memoir was considered to make the assessment too complicated and time consuming
• Assessors questioned whether 'experts' could be expected to have a good working knowledge of all the specified codes
• Determining some 'desktop' information may not be possible without extensive investigations
• The division of churches into 'observable spaces' can be approached in a number of ways
• The spatial configuration component is exceptionally hard to assess
• The components of furniture and furnishings, fixtures and fittings and building structure were also considered to be difficult to assess

The constructive comments from the 'expert' assessors provided invaluable information. Responses to these comments are to be incorporated into the 'second cut' survey guide and worksheets which is beyond the scope of this thesis. Many of the problems, it is believed, would be resolved if the assessors undertook further surveys with the procedure and became more familiar with its intended operation.

9.2.3.3 A feel for the repeatability of the developed procedure

The results of the fire safety assessment are shown in table 9.1. It can be seen that the total scores range from 214 to 263, a range of 49 points [10%]. It is interesting to observe that the six scores fall into three clusters which suggests that the assessors have approached the assessment with different mind-sets. Certainly in the case of the highest score cluster [made by the author and Dr Eric Marchant] a similar mind-set my be explained. These were the assessors with the greatest understanding of the procedure and they may have scored highest as positive contributions to safety were more readily identified and rewarded. The mind-sets of the other assessors are likely to have been influenced by their professional backgrounds, however, the results do not provide any clear evidence to support this.

Initially, these scores appear to be diverse, but if the individual component scores are reviewed a different picture emerges. Broadly, it can be interpreted from the results in table 9.2 that no major discrepancies in component scores were produced. It can be seen that in ten of the eighteen components [56%] cases, there is not more than a one point variation across the six assessors. This presents evidence to illustrate that, firstly, the worksheets in the ten component cases could be clearly interpreted and secondly, that there is a strong agreement in evaluation amongst the 'expert' assessors. Of the other eight components, only one component, manual fire fighting equipment has a result range of greater than two [a range of three]. This is surprising considering that the assessment is one of the least subjective of the worksheets, but clearly the results show that there were different interpretations on the value of the sub-components within the component. [See component worksheet in appendix G5].

A review of the total component scores shows there to be a range of eight [see table 9.2]. As a comparison, the repeatability tests results are compared to those carried out by four fire prevention officers during the development of the Edinburgh hospital fire safety evaluation scheme for patient areas within hospitals[1] [table 9.5]. As it can be seen in the first test a range of seven was recorded. If it is considered that in the church test six 'experts' were from different backgrounds [from which more diverse results would be expected] the results may be viewed as having as good a repeatability as can be expected at this initial trial stage.

Table 9.5: Comparison of 'expert' repeatability tests

Scheme	Number of expert participants	Outcome
Patient areas within hospitals[2]		
Test 1	4	mean 46.5, range 7
Test 2	4	mean 57, range 4
St Mary De Castro church	6	mean 43.5, range 8

Note: The Edinburgh hospital scheme has twenty components and the parish church scheme has eighteen components

9.2.4 Conclusions

The developmental surveys have generated a series of operational problems with the 'first cut' survey assessment procedure. The principal criticism being that of over-complexity of the worksheets. But despite these comments the repeatability has been shown to be as good as other developed evaluation procedures at this early trial stage. The 'second cut' survey guide and worksheets will address the problems encountered. It can be expected the repeatability would then be improved. Training and experience of the evaluation procedure would further enhance the consistency of the assessment outcomes.

9.3 Test 2: Repeatability surveys

9.3.1 The methodology

The aim of the test was to:

- evaluate the effectiveness of the fire safety element of the evaluation procedure when used by a 'semi-expert';
- test the repeatability of the procedure when used by 'semi-experts'.

The 'first cut' survey guide and worksheets [see appendix G5] were used for the repeatability test. The methodology involved the use of three final year Building Surveying degree students. They had a good existing knowledge of construction and building surveying approaches and techniques but only limited knowledge of fire safety

Table 9.6: Repeatability testing on five of the sample churches using three 'semi-experts' [continued]

	St Peter, Tilton-on-the-hill			St John, South Croxton		
Assessor	A	B	C	A	B	C
Components						
Access routes and exits*	4	5	3	4	4	2
Building services	1	2	0	2	3	1
Building structure	4	4	3	4	4	3
Detection and communication	3	2	3	2	3	3
Emergency lighting*	0	0	0	0	0	0
Furniture and furnishings	4	3	4	4	2	2
Fittings and fixtures	4	3	3	4	3	3
Housekeeping	1	0	2	1	0	1
Interior finishes*	3	3	1	4	4	2
Manual fire fighting equipment	3	3	2	3	3	3
Management systems	0	0	0	0	0	0
Passive protection*	4	3	2	1	3	2
Retrieval training and practice	1	1	0	1	0	0
Spatial configuration*	4	4	3	4	4	4
Security	2	3	1	2	1	1
Smoke control*	1	0	2	2	1	1
Suppression systems	0	0	0	0	0	0
The fire brigade	4	4	4	1	2	1
Totals	**43**	**40**	**33**	**39**	**37**	**29**
	mean 39 range 10			**mean 35 range 10**		

Notes: Totals are the sum of the eighteen components and have not been modified to reflect the importance of the components
* Fire safety assessment of the main worship area only

and so were considered to be 'semi-experts'. Before completing the surveys the students were given two hours training on how to undertake the evaluation as well as some refresher notes on architectural styles of churches and the principles of fire safety. The surveys were completed in one day. Five churches from the sample ten were used for the tests, each student undertaking their own assessment independently at each of the churches. Complete fire safety assessment scores for each church were not generated as only one 'observable space' [the main worship area] was assessed for those components identified in table 8.19.

9.3.2 The results

The results of the tests are shown in the table 9.6.

9.3.3 Discussion of the results

9.3.3.1 Accuracy and consistency of the results

Out of the 90 assessments [eighteen times five] made by the 'semi-expert' assessors 59 [66%] of the components were scored to within one point variation. While only three of the assessments had a variance of three [60%] which may be considered undesirable. Overall, It can be seen [table 9.6] that the range between the assessors' results fluctuated between churches. As the results are laid out in the order of assessment, it can be interpreted that the assessors did not converse or exchange views during the assessment period as the variance range does not decrease linearly. The average range between the 'semi-experts' results is 8.5. This is a little larger than the expert assessors [a range of eight] and thus the accuracy of the repeatability is not as refined. [It must also be appreciated there were six 'expert' assessors and only three 'semi-expert' assessors].

If the assessors' results are studied in detail it can be see that assessor C scored the lowest [combined score] for four out of the five churches. This suggests that the assessors 'mind set' when interpreting the scoring scale was different to the other two assessors. However, if the pattern of the results are considered, assessor C is shown to have the most consistent results. The results show assessor C to have scored eleven components two points different to the consensus compared to assessor A, five components and assessor B, seven components. But when comparing those scores three points adrift from the consensus [considered to be a maverick] assessor C has none compared to assessor A, one and assessor B, four. From this evidence it is considered that assessor C comes nearest to achieving an 'expert' profile.

By analysing the results those components with good and poor repeatability can beidentified. Those components for which the scores were least diverse include the following:

Table 9.7: Components with good repeatability[i]

Components	Comments
Emergency lighting and suppression systems	Because none of the churches contained either systems a simple no situation existed in all cases
Management and retrieval training and practice	Again none of the churches had any formal systems and so there was very little scope for diverse interpretations
The fire brigade, manual fire fighting equipment and detection and communication	All these components required evidence to be gathered and an assessment made in a structured manner
Furniture and furnishings, fittings and fixtures and building structure	It is surprising these components showed such good repeatability as the assessments are considered to be the most subjective

Note: [i] Good repeatability is taken as a component which has no greater than a one point variance in any assessment

Those components for which the scores were most diverse included access and exit routes, building services, housekeeping, passive protection, spatial configuration and security. The possible reasons for the poor repeatability are discussed in the next section.

9.3.3.2 Highlighting problem components

As an aspect of the de-briefing process the 'semi-experts' were asked to grade on a scale of one equals easy to three equals hard, how they found the evaluation of each of the components. It was considered there were two principle areas from which a misunderstanding could be generated:

- In the interpretation of what is required.
- In the observation of what is or is not present.

The assessors were asked to consider both these aspects when making their evaluations [see table 9.8].

Table 9.8: 'Semi-expert' assessors consideration of the ease of completion of the eighteen component worksheets

Assessor	A	B	C
Access routes and exits	1	1	1
Building services	2	3	3
Building structure	3	1	3
Detection and communication	1	1	2
Emergency lighting	1	1	1
Furniture and furnishings	3	1	3
Fittings and fixtures	3	1	3
Housekeeping	1	1	1
Interior finishes	3	3	2
Manual fire fighting equipment	1	1	2
Management systems	1	2	1
Passive protection	3	1	3
Retrieval training and practice	1	2	1
Spatial configuration	3	3	3
Security	2	2	2
Smoke control	1	1	1
Suppression systems	1	1	1
The fire brigade	2	1	2

Note: Where 1 = easy to complete to 3 = hard to complete

If data from tables 9.6 and 9.8 is compared, it can be seen that those components with large variance scores [components with greater than one point variance in any assessment] and those considered to be hard to conduct, do not match in all cases. Housekeeping and access and exit routes are shown to have a large score variance but considered to be easy to undertake. Clearly, in these two cases the 'semi-expert' assessors have made different interpretations of issues in the worksheet but found the conducting of the assessments straight forward. Similarly, the same explanation may be applied to the assessment of security, although the 'semi-experts' found the component only moderately easy to complete.

For the remaining large variance score components, however, there is a clear relationship between the large variance scores and the complexity of completing the assessment. The highlighted components and suggested reasons for their poor repeatability are detailed in table 9.9.

Table 9.9: Components with poor repeatability[1] and considered difficult to assess by the 'semi-experts'

Components	Comments
Spatial configuration	This is not surprising. Even the 'experts' found this one complicated. It is an important element of fire safety but not enough research has been done to fully understand the affect on fire of the interior of churches. Also it requires the assessor to think in a three dimensional context, which is a very complex requirement
Passive protection	The misunderstanding may have come from the fact that only one space was being assessed and to assess passive protection there is a need to enter the adjoining spaces
Building services	Confusion may be caused by the assessment structure

Note: [1] Components with a large score variance are considered to have poor repeatability

If evidence from tables 9.4. 9.6 and 9.8 is brought together, a clear picture of those components which can be considered problematic for 'semi-experts' can be established.

Table 9.10: Identification of problematic components

Components	Identified by 'semi-experts' as problematic [Table 9.8]	Large variance in component scores [Table 9.6]	Identified by experts as being problematic [Table 9.4]
Access routes and exits		*	
Building services	*	*	
Building structure	*		*
Detection and communication			
Emergency lighting			
Furniture and furnishings	*		*
Fittings and fixtures	*		*
Housekeeping		*	
Interior finishes	*		
Manual fire fighting equipm't			
Management systems			
Passive protection	*	*	
Retrieval training and practice			
Spatial configuration	*	*	*
Security		*	
Smoke control			
Suppression systems			
The fire brigade			

Notes: Table 9.8: at least two 'semi-experts' considered the component hard to assess
Table 9.6: score variance greater than one point
Table 9.4: noted as a complex component to assess by the 'expert' assessors

From table 9.10 it can be seen six components are highlighted as being considered problematic components from two of the three sources. If these six problem components are considered to represent 33% of the overall fire safety assessment, it can be crudely estimated that 'semi-experts' have the knowledge base adequate to handle 66% of the component worksheet assessments and to work within an accuracy range of +/- 20% [a one point variance]. The results of this repeatability test supports this argument.

9.3.4 Conclusion

This repeatability test has confirmed that the result of the assessment survey is likely to be more accurate when conducted by an 'expert' rather than a 'semi-expert' assessor. 'Semi-experts' only have the knowledge base to work to a sufficient accuracy with about 66% of the assessment. But this would be expected to improved if the problem components were refined as part of the 'second cut' survey.

The six identified problematic components in terms of understanding and assessment handling need specific attention during the 'second cut' survey development stage. The lack of understanding of spatial configuration is especially highlighted as being critical to the effective assessment of fire safety and it is suggested that some formal training in aspects of fire growth and smoke movement would be beneficial for assessors.

The repeatability tests have given an indication of the robustness of the survey assessment when used by 'semi-experts'. The further development of the procedure [to be undertaken outside the scope of this thesis] is likely to result in the production of a simpler-to-use and reliable assessment tool.

9.4 Test 3: Overall fire safety rating assessment

9.4.1 The methodology

The aims of this assessment were to:

- Demonstrate the practical operation and output of the complete evaluation procedure;
- Produce outputs to which approximate levels of acceptability can be placed.

Table 9.6: Repeatability testing on five of the sample churches using three 'semi-experts'

	St Andrew, Welham			St Michael, Cranoe			St Michael, Hallaton		
Assessor	A	B	C	A	B	C	A	B	C
Components									
Access routes and exits*	4	2	2	5	5	3	3	5	3
Building services	4	1	2	2	1	1	1	2	2
Building structure	5	4	4	4	4	3	3	4	4
Detection and communication	2	1	2	1	3	1	3	2	3
Emergency lighting*	0	0	0	0	0	0	1	0	0
Furniture and furnishings	2	3	3	2	3	2	3	4	3
Fittings and fixtures	4	3	4	3	3	3	4	4	3
Housekeeping	4	4	4	1	4	2	4	2	4
Interior finishes*	4	3	3	4	4	4	4	4	3
Manual fire fighting equipment	0	0	0	3	1	1	0	0	0
Management systems	0	0	0	0	0	0	0	0	1
Passive protection*	2	1	1	3	1	2	3	3	3
Retrieval training and practice	0	0	0	0	0	0	1	3	0
Spatial configuration*	5	5	3	5	4	3	2	4	1
Security	0	1	0	1	2	0	1	2	3
Smoke control*	1	0	0	1	0	2	1	0	3
Suppression systems	0	0	0	0	0	0	0	0	0
The fire brigade	2	4	1	2	3	2	4	3	3
Totals	**39**	**32**	**29**	**37**	**39**	**29**	**38**	**42**	**39**
	mean 33, range 10			**mean 35, range 8**			**mean 40, range 4**		

Notes: Totals are the sum of the eighteen components and have not been modified to reflect the importance of the components
*Fire safety assessment of the main worship area only

Table 9.11: Results of the individual elements of the fire safety evaluation procedure for the property protection of the ten parish churches in the Leicester Diocese

Church	**Fire Safety Measure [FSM] Opt. 1**	**Fire Safety Measure [FSM] Opt. 2**	**Functional Value [FV]** Average attendance	**Historic Value [HV]** Statutory listing	**Potential Maximum Loss [PoML]** % of complete building
All Saints, Wigston	272	278	22%	grade I	86
St Andrew, Welham	216	212	25%	grade II*	90
St John the Baptist, South Croxton	198	196	4%	grade II*	89
St Leonard, Swithland	189	189	35%	grade II*	84
St Mary, Barwell	276	273	7%	grade I	83
St Mary, Humberstone	207	206	18%	grade II	80
St Michael, Cranoe	199	194	20%	grade II*	85
St Michael, Hallaton	216	214	7%	grade I	88
St Peter, Copt Oak	223	228	11%	not listed	93
St Peter, Tilton-on-the-Hill	216	207	3%	grade I	88

Notes: FSM Option 1: Observable space results averaged to generate the overall building score
FSM Option 2: Area multiplier used on each observable space to generate the overall building score

Table 9.12: Fire safety measure summary results [average multiplier] FSM opt. 1

Components	Wigston		Welham		Croxton		Swithl'd		Barwell		Hum'ston		Cranoe		Hallaton		Copt Oak		Tilton	
	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii
Access route & exits	1	2	1	2	3	6	3	6	3	6	3	6	3	6	3	6	2	4	2	4
Building services	3	18	4	24	2	12	3	18	3	18	2	12	3	18	3	18	2	12	2	12
Building structure	4	16	4	16	4	16	4	16	4	16	4	16	4	16	3	12	3	12	2	8
Detection & commun.	3	18	2	12	2	12	1	6	3	18	3	18	1	6	3	18	0	0	2	12
Emergency light.	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0
Furniture & furnish.	3	15	4	20	4	20	3	15	1	5	1	5	2	10	4	20	5	25	3	15
Fixture & fittings	4	20	4	20	5	25	2	10	4	20	3	15	3	15	3	15	2	10	4	20
Housekeeping	4	28	4	28	2	14	4	28	3	21	3	21	4	28	4	28	3	21	3	21
Interior finishes	3	12	3	12	4	16	3	12	3	12	3	12	3	12	4	16	3	12	4	16
Manual fire fight. eq.	4	28	0	0	2	14	1	7	3	21	4	28	3	21	0	0	2	14	3	21
Management systems	2	26	0	0	0	0	1	13	3	39	1	13	0	0	0	0	1	13	0	0
Passive protection	4	20	2	10	4	20	3	15	4	20	3	15	2	10	3	15	4	20	4	20
Retrieval training	1	4	1	4	1	4	1	4	1	4	1	4	0	0	1	4	0	0	1	4
Spatial configuration	4	4	5	5	4	4	5	5	4	4	4	4	5	5	5	5	5	5	4	4
Security	2	8	3	12	2	8	3	12	3	12	4	16	2	0	2	8	3	12	2	8
Smoke control	1	5	3	15	3	15	2	10	2	10	2	10	4	20	3	15	3	15	3	15
Suppression systems	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
The fire brigade	4	48	3	36	1	12	1	12	4	48	1	12	2	24	3	36	4	48	3	36
Totals		**272**		**216**		**198**		**189**		**276**		**207**		**199**		**216**		**223**		**216**

Notes: [i] The assessed score for each component where 5 = a perfect contribution and 0 = a totally inadequate or non-existent contribution to fire safety for the whole building
[ii] The score for each component generated by multiplying the assessed score by the components contribution to fire safety [table 8.18]
For complete church titles see table 9.11

Table 9.13: Fire safety measure summary results [area multiplier] FSM opt. 2

Components	Wigston		Welham		Croxton		Swithl'd		Barwell		Hum'ston		Cranoe		Hallaton		Copt Oak		Tilton	
	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii	i	ii
Access route & exits	2	4	2	4	5	10	4	8	3	6	3	6	4	8	5	10	5	10	5	10
Building services	3	18	4	24	2	12	3	18	3	18	2	12	3	18	3	18	2	12	2	12
Building structure	4	16	4	16	4	16	4	16	4	16	4	16	4	16	3	12	3	12	2	8
Detection & commun.	3	18	2	12	2	12	1	6	3	18	3	18	1	6	3	18	0	0	2	12
Emergency light.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Furniture & furnish.	3	15	4	20	4	20	3	15	1	5	1	5	2	10	4	20	5	25	3	15
Fixture & fittings	4	20	4	20	5	25	2	10	4	20	3	15	3	15	3	15	2	10	4	20
Housekeeping	4	28	4	28	2	14	4	28	3	21	3	21	4	28	4	28	3	21	3	21
Interior finishes	3	12	3	12	4	16	3	12	3	12	3	12	4	16	3	12	3	12	3	12
Manual fire fight. eq.	4	28	0	0	2	14	1	7	3	21	4	28	3	21	0	0	2	14	3	21
Management systems	2	26	0	0	0	0	1	13	3	39	1	13	0	0	0	0	1	13	0	0
Passive protection	4	20	2	10	4	20	3	15	4	20	3	15	2	10	3	15	5	25	3	15
Retrieval training	1	4	1	4	1	4	1	4	1	4	1	4	0	0	1	4	0	0	1	4
Spatial configuration	3	3	4	4	3	3	3	3	3	3	3	3	4	4	3	3	4	4	3	3
Security	2	8	3	12	2	8	3	12	3	12	4	16	2	8	2	8	3	12	2	8
Smoke control	2	10	2	10	2	10	2	10	2	10	2	10	2	10	3	15	2	10	2	10
Suppression systems	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
The fire brigade	4	48	3	36	1	12	1	12	4	48	1	12	2	24	3	36	4	48	3	36
Totals		**278**		**212**		**196**		**189**		**273**		**206**		**194**		**214**		**228**		**207**

Notes: [i] The assessed score for each component where 5 = a perfect contribution and 0 = a totally inadequate or non-existent contribution to fire safety for the whole building
[ii] The score for each component generated by multiplying the assessed score by the components contribution to fire safety [table 8.18]
For complete church titles see table 9.11

Table 9.14: Overall fire safety rating [OFSR] scores options one to three [using FSM Opt. 2]

Churches	FSM Opt 2	FVR Opt. 1	OFSR Opt. 1	FVR Opt. 2	OFSR Opt. 2	Diff.[i]	FVR Opt. 3	OFSR Opt. 3	Diff.[ii]
All Saints, Wigston	56	51	**+4**	56	**0**	-4	59	**-3**	-7
St Andrew, Welham	42	49	**-7**	53	**-11**	-4	55	**-13**	-6
St John, South Croxton	39	43	**-4**	48	**-9**	-5	51	**-12**	-8
St Leonard, Swithland	38	52	**-14**	55	**-17**	-3	58	**-20**	-6
St Mary, Barwell	55	45	**+10**	51	**+4**	-6	55	**0**	-10
St Mary, Humberstone	41	36	**+5**	38	**+3**	-2	39	**+2**	-3
St Michael, Cranoe	39	47	**-8**	51	**-12**	-4	53	**-14**	-6
St Michael, Hallaton	43	51	**-8**	57	**-14**	-6	61	**-18**	-10
St Peter, Copt Oak	46	28	**+18**	29	**+17**	-1	29	**+17**	-1
St Peter, Tilton-on-the-Hill	41	50	**-9**	56	**-15**	-6	60	**-19**	-10

Notes: FSM scores normalised [max. 500]
FVR scores normalised [max. 3]
[i] Difference between OFSR Opt. 1 and OFSR Opt. 2
[ii] Difference between OFSR Opt. 1 and OFSR Opt. 3

Where FVR Opt. 1 = 2(0.5FV + 0.5HV) + PoML - FSM
FVR Opt. 2 = 2(0.4FV + 0.6HV) + PoML - FSM
FVR Opt. 3 = 2(0.33FV + 0.66HV) + PoML - FSM
OFSR = FSM - FVR

It was considered important at this embryonic development stage to carry out a set of complete evaluation procedure assessments in order to generate a series of overall fire safety ratings. [rather than develop the 'second cut' survey guide and worksheets].

The ten sample churches were used for this test. These assessments were completed by the author only. Appendix H1 details the key fire safety survey data observed. The fire safety assessment scores for the eighteen components in each church are displayed in appendix H2 and appendix H3 contains the elemental results of the overall evaluation procedure for each church.

9.4.2 The results

The results are shown in tables 9.11 to 9.14. [Refer also to section 7.3.5 which defines the relationships between individual elements of the evaluation procedure]

9.4.3 Discussion of Results

The results from the trial application of the evaluation procedure are presented showing a series of result options. These represent alternative calculation approaches and weighting options. All result options were presented to a sub-Delphi group consisting of three participants, through which expert intuitive judgement, supported by logical reasoning was used to make the option selection as discussed further in this section. This analysis considers the two key aspects of the procedure in turn [fire safety measure and the fire vulnerability rating] and then reviews the OFSR results.

9.4.3.1 The fire safety measure assessment

Two calculation approaches have been used to generate the complete building fire safety measure scores. As discussed in section 8.5.4, FSM opt. 1 uses the average of the 'observable space' scores to generate the whole building score [equation option 1], while FSM opt. 2 uses the area multiplier on each 'observable space' score to generate the whole building score [equation option 2].

Option 1

$$\mathrm{FSM}_{\mathrm{opt.1}} = \underbrace{\left\{ \sum_{j=1}^{6} \left[\sum_{i=1}^{n} \left(\frac{(\mathrm{obsp})_i}{n} \right) \right]_{\mathrm{component}\,j} \times \mathrm{con}_j \right\}}_{*} + \left\{ \sum_{m=1}^{12} (\mathrm{building})_m \times \mathrm{con}_m \right\}$$

Option 2

$$FSM_{opt.2} = \underbrace{\left\{ \sum_{j=1}^{6} \left[\sum_{i=1}^{n} \left(\frac{(obsp)_i \times a_i}{\sum_i a_i} \right) \right]_{component_j} \times con_j \right\}}_{*} + \left\{ \sum_{m=1}^{12} (building)_m \times con_m \right\}$$

where

j	= * components [table 9.6]
i	= number of 'observable spaces' for component j
m	= not * components
$(obsp)_i$	= score for 'observable space' i
$(building)_m$	= score for whole building of component m
con.	= contribution to fire safety

Note

$\sum_i a_i = A$ (whole building area)

As demonstrated in table 8.21 and shown in table 9.15 different results are produced by each calculation option. There is a variance of minus nine to plus six. In seven of the ten cases a higher score is achieved by using FSM opt. 1.

Table 9.15: Score differences: FSM opt. 2 from FSM opt.1

Church	Score difference
All Saints, Wigston	+6
St Andrew, Welham	-4
St John, South Croxton	-2
St Leonard, Swithland	0
St Mary, Barwell	-3
St Mary, Humberstone	-1
St Michael, Cranoe	-5
St Michael, Hallaton	-2
St Peter, Copt Oak	+5
St Peter, Tilton-on-the-Hill	-9

The sub-Delphi group felt that FSM opt. 1 in some situations did not accurately reflect the safety of the property. Particularly when the church consists of a larger number of small enclosures. In such cases, higher scores in a number of small enclosures can disguise a poor score in the largest enclosure as the scores carry the same weighting. FSM opt. 2, however, reflects the proportion of each enclosure and thus is more accurate as a system of assessment. FSM opt. 2, in addition, can be considered to be a unit rate score per square metre and can be used for budget evaluations. For this reason FSM opt. 2 is used in the overall fire safety rating calculations and all further evaluations of the FSM refer to FSM opt. 2.

Reviewing the FSM scores overall it can be seen that there is a broad variance in the scores [a range of 89 points from 189 to 278]. There are three clusters. Barwell and Wigston which score significantly higher than the average, while South Croxton, Cranoe and Swithland score significantly lower than the average and the remaining five churches sit between the two extremes. Such variance enables those churches with a lower level of fire safety to be clearly highlighted and provides evidence to suggest that the 'first cut' survey works as a means of structured assessment. The broad variance in scores demonstrates that the assessment mechanisms within the fire safety evaluation are effective at rewarding good fire safety and penalising poor fire safety.

When the scores are compared to the maximum score [500, see section 8.5.4] it can be seen that all the churches have a relatively low score. Barwell which achieves the best score of 278 is only 57% of the maximum and Swithland which scores the lowest score is 38% of the maximum. The results clearly show that the level of fire safety in the sample parish churches is considerably lower than the perfect level of fire safety set out in the 'collated norm'. Specifically, as shown in table 9.16, management systems, retrieval training and practice, suppression systems and emergency lighting have been shown not to be present in the majority of the sample. [In addition, detection and alarm systems are also very rare in churches, but human surveillance receives a credit in the component detection and communication and the mean score is two] [discussion as to the acceptable minimum level of fire safety takes place in section 9.4.4]

Table 9.16: Means scores across the ten sample churches

Components	Mean [score range 0 - 5]
Emergency lighting	0.1
Management systems	0.8
Retrieval training & prac.	0.8
Suppression systems	0

9.4.3.2 The fire vulnerability rating

Utilising the logic discussed in section 7.3.5, the fire vulnerability rating [FVR] is calculated using the following equation:

$$FVR = [[PoML - (FSM - (HV + FV))] + (HV + FV)]]$$

Giving:

$$FVR = 2(FV + HV) + PoML - FSM$$

Where

FV	= Functional value
HV	= Historic value
FSM	= Fire safety measure
PoML	= Potential maximum loss

The gathered data is shown in table 9.11. The functional value figures show a broad variance from 3% to 35%. This data clearly exposes those churches which are being under utilised. From the sample it is the larger rural churches which score the lowest functional value. Principally, St Peter, Tilton-on-the-Hill [3%] and St John the Baptist, South Croxton [4%]. The historic value data shows there is an example of each grading category in the sample, while in the case of the potential maximum loss the result are in a tight cluster ranging from 80% to 93%.

Table 9.14 shows three calculated options for the FVR. Each represents a different balanced weighting between the functional value and the historic value. The sub-Delphi group considered that an even weighting [FVR opt. 1] did not provide a true representation of building worth. Guidance was taken from the results of the Delphi group questionnaire that identified historic value as being more important than the functional value [section 8.6.1]. A two thirds [HV], one third [FV] balance caused the FVR to increase significantly from the FVR Opt. 1, particularly those churches with a grade I listing [See table 9.14]. The historic value weighting was then considered to be making too large a contribution. A decision was taken to use a sixty [HV], forty [FV] weighting [FVR Opt. 2], which sits between FVR Opt. 1 and Opt. 3. [see table 9.14]. The range of FVR Opt. 2 scores is shown to be from 57 [Hallaton] to 29 [Copt Oak].

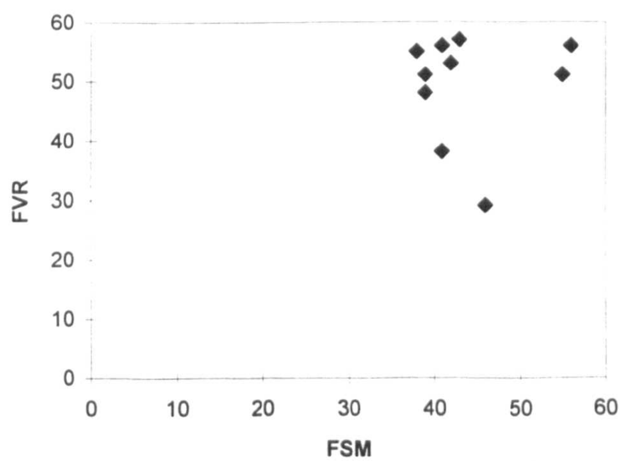
9.4.3.3 The overall fire safety rating

The overall fire safety ratings are shown in table 9.17 and in figure 9.1 [determined by deducting the fire vulnerability rating from the fire safety measure].

Table 9.17: Overall fire safety rating results for the ten sample churches

Churches	FSM Opt. 2	FVR Opt. 2	OFSR
All Saints, Wigston	56	56	0
St Andrew, Welham	42	53	-11
St John, South Croxton	39	48	-9
St Leonard, Swithland	38	55	-17
St Mary, Barwell	55	51	+4
St Mary, Humberstone	41	38	+3
St Michael, Cranoe	39	51	-12
St Michael, Hallaton	43	57	-14
St Peter, Copt Oak	46	29	+17
St Peter, Tilton-on-the-Hill	41	56	-15

Figure 9.1: Scatter plot of FSM versus FVR



The OFSR results from the sample churches test the effectiveness of the logic used to generate the inter-relationships between variables and provides the first evidence to question whether the output from the procedure does realistically balance the level of fire safety against the level of vulnerability. As displayed in the FSM and FVR results, the OFSR results have a broad spread. In terms of positive and negative outcomes there are three positive, six negative and one church in which the FSM equals the FVR. Such a broad spread of results around the zero origin suggests that zero does represent a suitable minimum acceptability level.

If select individual church results are reviewed, the flexibility of the assessment approach is clearly demonstrated. For example, both St Mary, Humberstone and St Peter, Tilton-on-the-Hill score a FSM of 41. For St Mary, the score is judged acceptable as the vulnerability of the building is low [38], while for St Peter the same FSM score is not acceptable as it's vulnerability is high [56]. Clearly, if resources were to be allocated to the church where the chance of the loss of valuable fabric is greatest, funds should be directed to St Peter.

Two key questions next need to be addressed regarding the acceptability of the procedure output:

- If zero is taken as a minimum acceptability level, what positive score difference between the FSM and the FVR can be considered to be desirable?
- Is there a need to set a minimum acceptable FSM score regardless of the FVR?

9.4.4 Estimating levels of acceptability

With the ten sample churches it is now possible to compare the overall fire safety ratings of each individual churches and to determine which churches are in most need of fire safety improvements. To do this it is necessary to compare the scores not only to the created standard [the 'collated norm'] but also to the level of fire vulnerability in each case to establish what is considered to be an acceptable outcome. So far, it has been considered that zero represents a minimum 'acceptable level'. But in reality it will be advisable to have a situation where the FSM exceeds the FVR so that the level of fire safety may be considered to be better then minimally acceptable. This position can be termed a 'desirable level' of fire safety. In practice, ultimately it is for the diocesan management to position a desirability level depending on the scope and level of resources available. At this embryonic stage an estimate can only be determined.

9.4.4.1 Methodology

An assessment of acceptability has been conducted on the global OFSR by means of observational judgements to firstly test the minimum acceptability level and also to suggest a desirability level. Two members of the Delphi group placed the ten churches into the following categories: good, average and poor in respect to the considered level of fire safety and categories: high, medium, low in respect to the considered vulnerability of the churches [see table 9.18].

Information was provided by means of photographs, survey notes and other necessary 'desk top' details. [but the OFSRs where not known to the participants]. The following results were produced.

Table 9.18: Category definitions

The level of fire safety	The considered vulnerability
Good: fire safety systems and measures judged to be good	High: impact loss and extent of fire loss considerable
Average: average level of fire safety systems and measures present	Medium: impact loss and extent of fire loss considered average
Poor: minimal fire safety systems and measures present	Low: impact loss and extent of fire loss minimal

9.4.4.2 Results

Table 9.19: Observational estimation of fire safety and vulnerability

Church	Fire safety	Vulnerability
All Saints, Wigston	good	high
St Andrew, Welham	poor	medium
St John, South Croxton	average	medium
St Leonard, Swithland	poor	high
St Mary, Barwell	good	high
St Mary, Humberstone	average	medium
St Michael, Cranoe	poor	medium
St Michael, Hallaton	average	high
St Peter, Copt Oak	average	low
St Peter, Tilton-on-the-Hill	average	high

9.4.4.3 Using the results

Working from the premise that if the FVR exceeds the FSM then that is an unacceptable situation the following acceptability judgements have been made [table 9.20]. These are then used to score the overall fire safety ratings [table 9.21].

Table 9.20: Acceptability judgements

The following results are considered as acceptable	
Fire safety	**Vulnerability**
good	high
average	medium
poor	low
And the following results are considered to be desirable	
fire safety	**Vulnerability**
high	medium
average	low

Table 9.21: Observational judgement assessment of the overall fire safety rating

Church	Fire safety	Vulnerability	OFSR
All Saints, Wigston	good	high	acceptable
St Andrew, Welham	poor	medium	unacceptable
St John, South Croxton	average	medium	acceptable
St Leonard, Swithland	poor	high	unacceptable
St Mary, Barwell	good	high	acceptable
St Mary, Humberstone	average	medium	acceptable
St Michael, Cranoe	poor	medium	unacceptable
St Michael, Hallaton	average	high	unacceptable
St Peter, Copt Oak	average	low	desirable
St Peter, Tilton-on-the-Hill	average	high	unacceptable

The results from the two approaches can be directly compared [table 9.22]. Although the results from the observational judgement do not reflect the evaluation results in all cases they provide enough evidence to make reasoned acceptability estimations. Most significantly, the results show that in nine out of the ten cases the observational assessments have mirrored the results from the evaluation procedure in identifying unacceptable and acceptable churches. This outcome, both provides evidence to support the effectiveness of the operational mechanics of the evaluation procedure and the use of zero as the minimum acceptability level.

Table 9.22: Comparison of observational judgement and evaluation procedure OFSR

Church	OFSR observational judgement	OFSR evaluation procedure
All Saints, Wigston	acceptable	0
St Andrew, Welham	unacceptable	-11
St John, South Croxton	acceptable	-9
St Leonard, Swithland	unacceptable	-17
St Mary, Barwell	acceptable	+4
St Mary, Humberstone	acceptable	+3
St Michael, Cranoe	unacceptable	-12
St Michael, Hallaton	unacceptable	-14
St Peter, Copt Oak	desirable	+17
St Peter, Tilton-on-the-Hill	unacceptable	-15

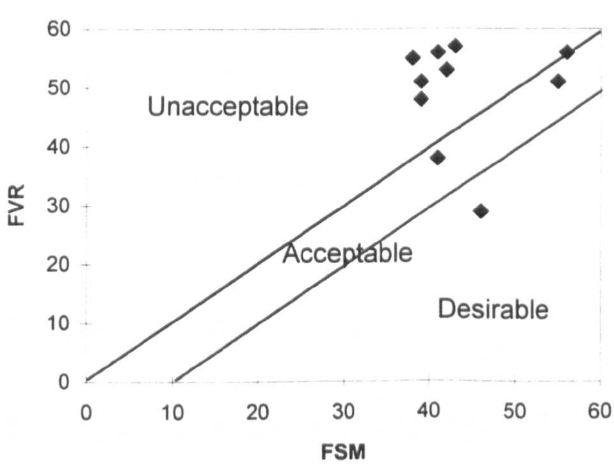
In the observational judgement evaluation only one church is identified as having a desirable outcome [Copt Oak, plus seventeen] while Barwell recorded the next highest score [plus four] and is assessed as acceptable. Using these results as a guide it has been decided to set the desirable level of fire safety at plus ten and above at this initial development stage. With further testing this boundary may change. This gives the following assessment cut off levels [table 9.23].

Table 9.23: Confirmed acceptability levels

OFSR <0	**unacceptable:** The level of first safety is considered not to be high enough for the fire vulnerability level of the building
OFSR 0 - 10	**acceptable:** The level of fire safety is considered to be only adequate for the fire vulnerability level of the building
OFSR >10	**desirable:** The level of fire safety is considered to be good for the fire vulnerability of the building

The acceptability and desirability boundaries can be applied to the OFSR scatter graph as shown in figure 9.2.

Figure 9.2: Scatter diagram of FSM versus FVR with acceptable and desirable cut off levels



Finally, concern was expressed amongst the Delphi group participants that a minimum FSM be set regardless of the level of vulnerability of the building to ensure that a certain level of fire safety is present. The observational judgement results in table 9.20 identified three churches as having a poor level of fire safety, St Michael, Cranoe [194], St Andrew, Welham [212] and St Leonard, Swithland [196]. Using these assessments as indicators a score of 200 is suggested [60% deficiency from the norm]. In respect to the ten sample churches, all are required to achieve a FSM of over 200 to gained a minimum acceptable level of fire safety.

9.4.5 Conclusion

The OFSR assessment trial has demonstrated the effectiveness of the evaluation procedure as a structured assessment tool. The broad spread of results around the zero origin suggests that zero does represent a suitable minimum acceptability level.

The observational judgement tests support the effectiveness of the operational mechanics of the evaluation procedure and the use of zero as the minimum acceptability level. A 'desirable level' of fire safety of plus ten is set, although the procedure has the flexibility to allow diocesan management to raise or lower the desirability level to suit resources and management decisions. A FSM score of 200 is suggested [60% deficiency from the norm] as a minimum fire safety level regardless of the assessed vulnerability of the building.

From the ten sample churches six score unacceptable fire safety ratings and only one achieves a desirable outcome. The scores indicate that nine out of the ten churches require some degree of upgrade in their existing fire safety level. The principle fire safety measures currently not present in parish churches are, suppression systems, detection and alarm systems, emergency lighting as well as management systems including item retrieval training and practice. The installation of such measures as detailed in the 'collated norm' would rise the level of fire safety at most parishes considerably.

9.5 Fire safety strategy

9.5.1 Fire safety strategy development

Six of the sample churches are shown to exhibit a level of fire safety which is unacceptable for the vulnerability level of the building. For such churches the implementation of a fire safety strategy as shown in figure 9.3 is necessary.

As identified in figure 9.3 the creation of an effective strategy requires both an evaluation of the existing state of fire safety in the property [This may be the results of the fire safety assessment and/or more in-depth investigations into certain aspects of the building] and a 'least-cost upgrade' [see glossary for definition] analysis, to enable a cost effective upgrade programme to be developed. This thesis does not ventured into the area of

Figure 9.3: Fire safety strategy flow diagram

Figure 9.3: Fire safety strategy flow diagram

1. Evaluate fire safety assessment outcomes

↓

2. Identify potential fire safety component upgrades

↓

3. Cost options

↓

4. Accept or modify proposals

↓

5. Calculate cost of upgrades [unit costs or cost per element]

↓

6. Develop an effective implementation strategy

strategy implementation, but a demonstration of the various approaches to 'least-cost upgrade' evaluation are outlined to illustrate the utility of the assessment output.

Firstly, using the confirmed acceptability levels in table 9.23 it is possible to evaluate the upgrade points necessary for each of the sample churches. From table 9.24 it can be seen that the largest FSM upgrade is required by St Leonard, Swithland. [A 85 point FSM upgrade to an acceptable level of fire safety and a 135 points upgrade to a desirable level of fire safety] [see example in section 9.5.2.1].

Although St Leonard, Swithland requires the largest FSM upgrade it is interesting to note that due to the varying levels of property vulnerability St Leonard, Swithland does not require the highest level of fire safety. Due to the assessed high vulnerability of the property, St Michael, Hallaton requires a FSM score of 334 [33% deficiency from the maximum score] to achieve a desirable level of fire safety. Similarly, All Saints, Wigston and St Peter, Tilton-on-the-Hill require a higher level of fire safety than St Leonard, Swithland [see table 9.25].

Table 9.24: Upgrade points required to achieve an acceptable and desirable level of fire safety

Church	OFSR	Upgrade points to an acceptable level	Upgrade points to a desirable level
All Saints, Wigston	0	--	50
St Andrew, Welham	-11	55	105
St John, South Croxton	-9	45	95
St Leonard, Swithland	-17	85	135
St Mary, Barwell	+4	--	30
St Mary, Humberstone	+3	--	35
St Michael, Cranoe	-12	60	110
St Michael, Hallaton	-14	70	120
St Peter, Copt Oak	+17	--	--
St Peter, Tilton-on-the-Hill	-15	75	125

Table 9.25: Fire safety measure scores required to achieve an acceptable and desirable level of fire safety

Church	OFSR	FSM score for an acceptable level	FSM score for a desirable level
All Saints, Wigston	0	-- [278]	328
St Andrew, Welham	-11	267	317
St John, South Croxton	-9	241	291
St Leonard, Swithland	-17	274	324
St Mary, Barwell	+4	-- [273]	303
St Mary, Humberstone	+3	-- [206]	241
St Michael, Cranoe	-12	254	304
St Michael, Hallaton	-14	284	334
St Peter, Copt Oak	+17	-- [228]	-- [228]
St Peter, Tilton-on-the-Hill	-15	282	332

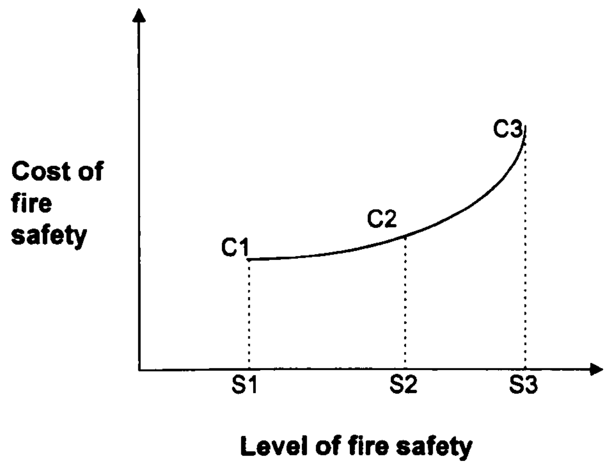
Note: [*n*] = score actually achieved

9.5.2 The concept of 'least-cost upgrade' analysis

There are examples of least-cost optimisation software programmes which have been written for 'unique occupancy' fire safety assessment schemes[3]. Such programmes have utilised mathematical optimisation techniques to identify the least-cost means of upgrade.

As shown in figure 9.6 an increase in the level of fire safety will result in an increase in the cost of fire safety. Though the improvement cost curve does not in reality remain constant. There are always some fire safety improvement which are cheaper to implement and yield a large safety increase and other systems which exhibit the opposite characteristics. Furnished with the evaluation procedure results it is possible to analysis options and propose a 'least-cost upgrade' solution.

Figure 9.6: Costs as a function of the level of general safety being produced[4]



A link between potential improvements in the survey scores and the actual cost of making improvements is a very attractive proposition. Illustrated below are a series of examples of how such analysis's may work. It is appreciated that in reality 'least-cost upgrade' analysis would involves many more variables than just the simple cost of the fire safety system. Such aspects as market factors, and aesthetic acceptability issues would also influence the ultimate decision.

Various approaches can be used, of which three are explored in more detail.

Table 9.27: 'Least-cost upgrade' approaches

Approaches
Approach 1: £*n*/m² improvement cost per FSM point. This can be used to enable an approximate figure to be quickly generated to provide an indication to the PCC of the cost of upgrading the FSM score to an acceptable or desirable level
Approach 2: £*n*/component improvement cost. A number of cost options can be generated to find the cheapest option which offers the greatest potential for increase in fire safety
Approach 3: It is possible to select a package of specific improvements to increase fire safety at different stages in the development of a fire. This can be achieved by establishing what components have the largest contribution to certain tactics

9.5.2.1 'Least-cost upgrade' analysis: St Leonard, Swithland

The evaluation procedure highlights Swithland as having the largest unacceptable overall fire safety rating. To investigate the fire safety improvement options it is necessary to analysis the results of the FSM in detail. The component score breakdown is shown in table 9.27.

Table 9.27: FSM opt. 2 scores for St Leonard, Swithland

Components	FSM opt. 2	% Contribution	Totals
Access route & exits	4	2	8
Building services	3	6	18
Building structure	4	4	16
Detection & communication	1	6	6
Emergency lighting	0	2	0
Furniture & furnishings	3	5	15
Fixture & fittings	2	5	10
Housekeeping	4	7	28
Interior finishes	3	4	12
Manual fire fighting equipment	1	7	7
Management systems	1	13	13
Passive protection	3	5	15
Retrieval training	1	4	4
Spatial configuration	3	1	3
Security	3	4	12
Smoke control	2	5	10
Suppression systems	0	8	0
Fire brigade	1	12	12
			Total: 189

Here the three 'least-cost upgrade' approaches detailed in table 9.26 are applied to St Leonard.

9.5.2.1.1 Approach one

Approach one establishes an approximate improvement figure expressed as a cost per metre squared per fire safety measure point. This unit rate figure can be determined by calculating the installation costs of the range of assessed fire safety systems and then by dividing the cost by the point increase generated by the installation of the system. This figure may be applied to each church assessed and provides an instant indication of the upgrade cost and enables a league table of church upgrade priorities to be created. As a starting price in this example, the cost of only three components has been estimated and the mean calculated.

Table 9.28: Improvement cost estimations[5]

Fire safety system	Installation cost	Score increase	Improvement cost per m² per point
Detection and alarm system	£10/m²	5 x 6 = 30	£0.33/m²/point
Sprinkler system	£30/m²	5 x 8 = 40	£0.75/m²/point
Emergency lighting	£8/m²	5 x 2 = 10	£0.8/m²/point
		Average: Unit rate improvement cost: £0.6/m²/point	

So for St Leonard, Swithland, with a floor area of 231m², to achieve an acceptable OFSR the fire safety improvement cost would be in the region of £11,781 and to achieve a desirable OFSR in the region of £18,711.

9.5.2.1.2 Approach two

This approach requires that the deficiencies in component scores are examined in each individual case and the improvement cost calculated on an individual building basis. If the most cost effective package possible is the priority then improvements in the components are based around the cheapest for the greatest point yield. It needs to be appreciated that a one point increase in the score of management systems would yield a thirteen point increase in the FSM as opposed to building services which would yield only a three point increase. So it is logical to concentrate on upgrading those high value components first.

As previously stated, a 85 point improvement in fire safety is required to bring St Leonard's to an acceptable level and 135 points to a desirable level. Considerable combinations of component improvements exist as shown in table 9.29. In terms of improvement costs it is possible to calculate the cost of each component. Initially, a cost of achieving a non-deficient component is needed. [A component that scores five]. Then that cost could be divided by five to give the cost of achieving each point on the 'Likert-type' scale. Some components which are clearly defined fire safety measures are easier to calculate than those which are an amalgamation of features. Costing of components is not undertaken in this thesis.

Table 9.29: Score up-grade options for St Leonard, Swithland

Components	FSM opt. 2 [score deficit]	% Contribution	Maximum point upgrade
Access route & exits[i]	0	2	0
Building services[i]	1	6	6
Building structure[i]	0	4	0
Detection & communication	4	6	24
Emergency lighting	5	2	10
Furniture & furnishings	2	5	10
Fixture & fittings	3	5	15
Housekeeping	1	7	7
Interior finishes[i]	1	4	4
Manual fire fighting equipment	4	7	28
Management systems	4	13	52
Passive protection[i]	1	5	5
Retrieval training	4	4	16
Spatial configuration[i]	1	1	1
Security	2	4	8
Smoke control	3	5	15
Suppression systems	5	8	40
Fire brigade	4	12	48

Note [i] Components to which the 'maximum attainable' score is four [not five]. See appendix H4

9.5.2.1.3 Approach three

As illustrated and discussed in chapters seven and eight the hierarchy of fire safety consists of six tactics, each of which play a role in fire mitigation. The tactic of prevention is the first and arguably the most important tactic. If prevention is successful the other intervention systems are not required. Thus using this premise it is logical to focus the improvements on those fire safety systems which provide a significant contribution to prevention specifically. Using tables 9.29 and table 9.30 a number of options can be given.

Table 9.30 can serve as a guide for the assessor in selecting a package of improvements. It can be seen [table 9.31] that those components with a large contribution to prevention are building services, housekeeping, management systems, security and the fire brigade.

Table 9.30: Components with significant contributions to specific tactics

Tactics	1.	2.	3.	4.	5.	6.
Components						
Access route & exits						*
Building services	*					*
Building structure				*		
Detection & communication		*				
Emergency lighting						*
Furniture & furnishings					*	
Fixture & fittings					*	
Housekeeping	*					
Interior finishes					*	
Manual fire fighting equipment			*		*	
Management systems	*	*	*	*	*	*
Passive protection				*	*	
Retrieval training					*	*
Spatial configuration						
Security	*					
Smoke control				*	*	
Suppression systems			*	*	*	
Fire brigade	*		*	*	*	*

Note: * = > 0.60 contribution recorded by the Delphi group
Tactics: 1. = Prevention, 2. = Communication, 3. = Extinguishment, 4. = Containment, 5. = Damage limitation, 6. = retrieval

Table 9.31: Maximum upgrade using only high prevention contribution components for St Leonard, Swithland

Maximum point increase	Score increase
4 point increase in management systems	52
4 point increase in the fire brigade	48
2 point increase in security	8
1 point increase in housekeeping	4
1 point increase in building services	3
	Total 115

In this case a maximum of 115 points can be achieved, so an upgrade to the desirability level could not be gained by focusing on high contribution prevention components only. [as an upgrade of 135 points is necessary]. This approach presents a cost for the upgrade of components which would enhance the prevention tactic specifically and may not serve as the most cost effective package possible.

This section has only demonstrated the utility of 'least cost upgrade' analysis and the versatility of the evaluation procedure in enabling a direct link to be made between the fire safety measure and the cost of making fire safety improvements. The development of a 'least-cost upgrade' tool for the evaluation procedure represents a major piece of proposed future research [see section 10.3.1].

9.6 Verification of the evaluation procedure

It is argued by Watts[6] and Shields[7] that for most fire safety assessment schemes there is very little information on methodology or evaluation criteria. Most available literature details the operational structure of such schemes only. Watts[8] further identifies that ranking approaches have high utility due to the relative ease of application but lacks validity because of the unspecified nature of the selection of variables and their relationships.

9.6.1 The methodology

In this thesis every attempt has been made to make each step in the developed protocol as transparent as possible. A clear presentation structure and detailed appendices support this hypothesis. While a comprehensive verification can only take place after further testing and general exposure, a broad evaluation is conducted at this stage of development.

Evaluation criteria was initially drafted, but after further consideration a published list of criteria for the assessment of an effective fire safety evaluation system by Watts[9] was selected for use.

9.6.2 Results

Table 9.32: Ten criteria for the effective development of fire safety assessment schemes[10]

Criteria	Evaluation procedure for the property protection of parish churches: Identification of steps taken
Criterion 1: Development and implementation of the method should be thoroughly documented according to a standard procedure	A detailed account of the procedures development and application is presented in this thesis [chapter seven to nine]
Criterion 2: Partition the universe rather than select from it [detail the mechanics of the procedure]	This is laid out in chapter seven and undertaken by the Delphi group. [chapter eight]

Table 9.32: Ten criteria for the effective development of fire safety assessment schemes[11] [continued]

Criterion 3: Parameters should represent the most frequent fire scenarios	An assessment of past fire experiences is taken from a review of past fire statistics [chapters four and six] and from prior knowledge acquisition [chapter eight]
Criterion 4: Provide operational definitions of parameters	The survey guide which accompanies the worksheets contains clear definitions of key terms [appendix F4]
Criterion 5: Elicit subjective values systematically	Achieve through the use of a Delphi group. The methodology and the detailed results are covered in chapter eight
Criterion 6: Parameter values should be maintainable [amenable to updating]	This aspect has not been considered in the development
Criterion 7: Treat parameter interactions consistently	The procedure uses a hierarchical interaction matrix to systematically assess potential relationships among all the parameter [chapters seven and eight]
Criterion 8: State the linearity assumption	The procedure uses a hierarchical interaction matrix to systematically assess potential relationships among all the parameters [chapter seven and eight]
Criterion 9: Describe fire risk in a single indicator	This is achieved by the overall fire safety rating [OFSR] [chapter nine]
Criterion 10: Validate results	The results are validated [at this initial stage] by the observational judgement exercise [chapter nine]

9.6.3 Discussion of results

It is considered that nine out of the ten criteria have been effectively employed in the development of this evaluation procedure. Such evidence reinforces the effectiveness of the methodology and the clarity of the protocol. This demonstration of the procedures credibility presents a case for the positive verification of the scheme at this initial stage.

9.7 Assessing the effectiveness of the development and application

In the creation and trial application of this 'unique occupancy' fire safety evaluation procedure, a series of developmental problems have been addressed [as initially outlined in section 7.3.1] and solved. To aid in an analysis of the effectiveness of these solutions, four questions are posed and answered: [reference to the questions and answers presented prior its development, identifying the required focus of the evaluation procedure may be beneficial. See section 7.7.1.1]

- Is the procedure assessing what is intended?

- Is the survey approach laid out in a user-friendly format?
- How accurate are the results generated from the procedure?
- Is the procedure shown to have a positive contribution to property fire safety management in parish churches?

9.7.1 Questions and answers

Is the procedure assessing what is intended?

The trial test results in this chapter have demonstrated that the evaluation procedure does achieve a systematic balanced assessment of fire safety and property vulnerability to fire. The procedure has been shown to have the capacity to highlight high vulnerability, low fire safety properties as having the largest fire safety deficiency. Post-assessment 'least-cost upgrade' approaches enable a cost effective fire safety strategy to be developed. In achieving this assessment, however, 'expert' knowledge decision making has been used, which may be considered to be a weakness in the operation of the procedure. At this embryonic developmental stage the variable relationships and weightings used are considered to be adequate to enable the process of the evaluation procedure to be realistically demonstrated, but further 'expert' knowledge acquisition exercises are necessary to generate a comprehensive verification of the procedure.

Is the survey approach laid out in a user-friendly format?

As highlighted in chapter nine, the component survey worksheets are considered to be over-complicated in their layout and assessment approach, so in that context, the procedure can be accused of not being effective. However, consideration has to be given to the fact that the worksheets are currently only at the 'first cut' stage of development. Previously developed assessment procedures have shown that four stages of development are needed before a good workable format is achieved[12].

How accurate are the results generated from the procedure?

The small scale repeatability tests have shown that when used by 'expert' assessors the results can be expected to be within +/-10%. The emphasis of this research programme has been placed on developing a robust protocol for the procedure. It is intended that the field tests shall address in detail the issues of accuracy and validity.

Is the procedure shown to have a positive contribution to property fire safety management in parish churches?

A case has been presented throughout the thesis that the evaluation procedure represents a tool, which if applied, will contribute to the loss minimisation of the unique fabric and content of parish churches. The response from individual members of the Leicester Diocese is very positive in terms of the value they consider it can have in the fire safety management of parish churches. With the results from field tests, a more informed and detailed case will be presented to parish councils and the diocesan management on the ultimate utility of the procedure.

9.7.2 Aspects to be resolved

In developing the evaluation procedure two key issues have yet to be satisfactorily resolved:

1. The repeatability of the procedure: the robustness of the procedure in terms of the knowledge level of the assessors.
2. The reproducibility of the procedure: the effectiveness of the procedure across a national range of parish church styles.

9.7.2.1 The repeatability of the procedure

Establishing a robust repeatability profile for the procedures is essential to give it credibility as an assessment tool. At this 'first cut' stage it has been shown that the assessment can only be effectively conducted by 'expert' assessors. 'Semi-experts' are considered to have the knowledge base adequate to handle approximately two thirds of the assessment. It is considered, however, that the development of the 'second cut' survey may improve the ability of semi-expert assessors in conducting the evaluation procedure. A series of field tests are required to generate evidence to further address this issue.

9.7.2.2 The reproducibility of the procedure

Equally the versatility of the procedure can only be illustrated once the extent of its reproducibility can be demonstrated. The trial application tests have been conducted on a localised sample of parish churches which conform to the conventional layout configuration of historic churches. It has been argued that the principles used are applicable to churches of all styles, layouts and ages of construction, but only after extensive reproducibility field tests can its application in a broader national context be confirmed.

9.8 Summary

This chapter has demonstrated the ultimate utility of the developed fire safety evaluation procedure for the property protection of parish churches. The credibility of the evaluation procedure is supported by the broad spread of the ten OFSR results. Zero is confirmed as being a minimum acceptability level and plus ten as a desirable outcome is suggested. In practice, ultimately it is for the diocesan management to position a desirability level depending on the scope and level of resources available.

From the ten sample churches six scored unacceptable fire safety ratings and only one achieved a desirable outcome. The scores indicate that nine out of the ten churches require some degree of upgrade in their existing fire safety level. The principle fire safety measures identified as currently not being present in parish churches are, suppression systems, detection and alarm systems, emergency lighting, management systems and retrieval training and practice. The installation of such measures as recommended in the 'collated norm' would substantially increase the level of fire safety at most parish churches.

Problems with the 'first cut' survey guide and worksheets have been identified. The principal criticism being the over-complexity of the worksheet. Six problematic components [building services, building structure, furniture and furnishings, fittings and fixtures and spatial configuration] in terms of assessor understanding and assessment handling have also been identified and will be addressed in the 'second cut' survey stage.

Despite these developmental problems a respectable repeatability level has been recorded with 'expert' assessors, while 'semi-expert' assessors have been shown to be able to handle about two thirds of the survey with a good degree of accuracy. Although the trial application tests have indicated that the procedure is currently only robust enough to be used by 'expert' assessors, further development is likely to result in the production of a simpler-to-use and reliable assessment tool.

The versatility of the assessment output is demonstrated through the suggested three approaches to 'least-cost upgrade' evaluation. This aspect of the enquiry is only outlined in the thesis, but is seen as a major aspect of further research. Similarly, the verification of the evaluation procedure is only conducted in the context of the limitation of the present research, however, the clarity of the developed protocol and the positive verification of the scheme is effectively detailed.

In developing the evaluation procedure two key issues have yet to be satisfactorily resolved. Field tests are required to confirm the accuracy of repeatability when used by both 'experts' and 'semi-experts' and similarly field tests are necessary to determine the scope of the procedures reproducibility in terms of churches styles, location, layouts and ages of construction.

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CHAPTER TEN

CONCLUSIONS AND FURTHER RESEARCH

10. CONCLUSIONS AND FURTHER RESEARCH

10.0 Introduction

In this chapter the outcomes of the thesis are summarised and the application of the conclusions identified. Recommendations for improving fire safety management in parish churches are then presented. Future development work on the evaluation procedure and areas for further research are outlined and finally, consideration is given to whether the thesis has provided sufficient evidence to support the hypothesis.

10.1 Conclusions

In this thesis the following hypothesis has been tested:

A formal system for the evaluation of fire safety in parish churches would be a valuable tool, offering simple, repeatable techniques for assessment, an immediate appraisal of acceptability and a method for the rapid identification of deficiencies. This could facilitate the adoption of a suitable, cost effective fire safety strategy.

In testing the hypothesis a series of conclusions have been reached. During the discussion of these conclusions the reader may wish to refer to figure 1.2, [chapter one] which illustrates the structure of the discussion.

10.1.1 Context of the problem

- There is an overwhelming need in terms of educational, historical, aesthetic and commercial reasons to support the preservation of historic buildings. All historic buildings exist in an environment that continuously threatens to deteriorate or destroy the fabric of properties. Fire is identified as being the agent of destruction with the greatest potential to cause total destruction, with the resulting disappearance of unique heritage and financial loss.
- Incidences of fires in churches is shown to be higher than all other historic building types. Malicious actions (arson) accounts for at least 47% of church fires. It is considered that churches have become soft targets for theft, vandalism and fire attacks and statistics from the EIG show there is currently no decline in the trend.
- In this thesis it is shown that danger to life from fire, in parish churches is not high, due to the facts that the natural layout of churches generally facilitates good

evacuation routes and travel distances. The threat to the fabric and content of parish churches however, is considerable. The parish churches of England and Wales, as a collection, are arguably the finest example of ancient churches in the world. The exceptional quality of church property, means that the loss of fabric and content is a loss to the cultural heritage of our nation. In addition, as a consequence of property fire damage the mission continuity of parish churches may also be disrupted causing functional and economic loss.

- The financial cost of the loss of church fabric is estimated to be around £5.3 million per year [table 3.2]. It is the responsibility of parochial parish councils to insure their church against the risk of property loss from fire. However, from the experience of recent past fire incidents it is has been discovered that the restoration costs of parish churches are much higher than previously calculated. Consequently, many parishes with limited resources can not afford to insure their churches for the full rebuild cost and the churches are under insured. This is creating a potential situation, where by, in the event of a major fire, without additional funds from the parish, it will not be practicable to restore the fabric of the building.
- There does not exist, at present, any formal policy within the church of England concerning the fire protection of parish churches. The autonomous approach to parish church property management undertaken by parochial parish councils, prevents the effective implementation and enforcement of diocesan wide fire safety policies or the utilisation of fire safety management tools. This issue has been extensively debated in this thesis. A decision making tool, in the form for a fire safety evaluation procedure is offered which if implemented successfully may provide the vehicle for a more integrated approach to fire safety management of parish churches.

10.1.2 The evaluation procedure

- This work has been shown that parish churches present a unique and complex environment. The physical structure and layout of churches, their range of uses and their style of management create a set of circumstances which make the approach to fire protection different from all other historic building types.
- Research in this thesis has highlighted a number of key issues regarding the behaviour of fire in parish churches and the behaviour of parish churches subject to fire. A fire growth analysis has identified that once a fire is established, the large enclosure sizes, window shape and means of ventilation in churches are conducive to greater fire severity. In addition, the risk of fire spread is further compounded by the

limited fire safety measures that are likely to be present. Specifically it has been shown that the presence of fire detection and alarm systems to achieve early detection and of sprinkler systems for automatic suppression, are extremely rare in parish churches. Property loss from fire is further threatened as often fire attack by the fire brigade may be hampered by churches being in remote locations, there being restricted access for fire appliances and the water supply limited or not present at all.

- In managing fire safety in churches three key issues present themselves: that of amateur management, scarce funds for building maintenance and the need for extreme sensitivity in the installation of active and passive fire precautions measures.
- In response to the issues summarised above this thesis sought to develop the protocol of an evaluation procedure to assess the level of fire safety in individual churches prior to the development of building specific fire safety strategies sensitive to the potentially exceptional quality of the fabric and contents. No such systematic procedure for parish churches previously existed. It was initially identified that such a procedure would play a valuable role in both aiding the diocesan management in allocating scarce resources amongst their ecclesiastic estate, and the PCC or guardians of individual churches in taking fire safety management decisions. In addition, it was noted that the evaluation procedure may be utilised by a fire engineer, insurance surveyor or building contractor as a risk assessment tool.
- Four 'unique occupancy' 'points schemes' were initially reviewed to determine whether an existing scheme could be directly applied to parish churches. Test applications were not successful however. The unique nature of the problem called for the need to create a procedure specific to churches. The Edinburgh hospital scheme was selected as the footprint for the development of the unique evaluation procedure for three reasons. Firstly, it offered a model suitable for a fire stage assessment, secondly it utilised a hierarchical process of analysis and thirdly, the author had access to the detailed research notes enabling a comprehensive understanding of the scheme to be gained.
- The developed evaluation procedure [Fire[SEPC]] is a knowledge based approach appropriate for a first stage assessment. The procedure balances the vulnerability of church property to fire against the fire safety of its fabric and content. It acts as a simple, repeatable technique for the immediate appraisal of acceptability at an initial stage evaluation level and as a method for the identification of deficiencies. Further investigative surveys and quantitative simulation techniques may be deployed to examine highlighted problems in greater detail, but such assessments reside beyond

the scope of this research project. The procedure is unique in that it is an original scheme developed for an 'unique occupancy'. Although the procedure has used an existing assessment format it has been extensively rethought and applied to a new set of spaces that demand an unique approach. Further aspects are also unique. Firstly, the procedure assesses the fire safety of the property and not life safety, as in the Edinburgh hospital scheme. And secondly, the assessment of overall fire safety includes an independent evaluation of the vulnerability of fabric and contents. No other known 'unique occupancy' fire safety assessment scheme undertakes such an evaluation configuration.

- Evidence from previous research identified that the technical parameters of fire safety are very complex and involve a network of interacting components. To handle such complexities this procedure has used a hierarchical approach to manage the complexity of the problem and an 'expert knowledge' method (Delphi group) to develop weightings and inter-relationship logic for both the fire safety variables and the fire vulnerability variables. In addition, a suitable comparator has been created to give the procedure a norm against which a judgement of deficiency is made. It has been shown that comprehensive guidance on fire safety in churches does not exist in a single document. To compensate for this a 'collated norm' document was specifically assembled from a range of documents for the purpose of this procedure.
- Preceding the development of the procedure a series of application trials were undertaken to aid the further development and refinement of the scheme and to give a simple measure of its ultimate utility. The results of the 'first cut' survey guide and worksheets pilot tests showed a 10% variance between the expert assessors scores. This variance compares favourably to the first field test results undertaken in the development of the Edinburgh hospital scheme. Thus it is suggested that the procedure is robust enough to work effectively when used by expert assessors only at this initial trial stage. It is anticipated that repeatability will be improved further after the development of the 'second cut' survey worksheets. Assessor training will further enhance the consistency of the assessment outcomes.
- The credibility of the evaluation procedure as an effective structured assessment tool is supported by the broad spread of the OFSR pilot test results, although further field tests are required to substantiate these initial findings. The observational judgement tests, which mirrored the OFSR procedure assessments in nine out of the ten cases, provide further positive evidence to indicate that the operational mechanics of the developed procedure does function as a realistic fire safety assessment tool.

- In this thesis the versatility of the developed procedure has only been demonstrated. It has been stressed throughout that an essential feature of the procedure is the facility to make direct links between potential improvements in the assessment score and the actual cost of making fire safety improvements. This link enables a cost-effective approach to fire safety improvements to be taken. Three suggested approaches to 'least-cost upgrade' analysis for fire safety improvements are outlined. The testing of these approaches on the developed procedure presents a major piece of future research as noted in section 10.3.1.

10.2 Application of the conclusions

The conclusions in section 10.1 have summarised the outcomes of this thesis. Consideration is now given to the utilisation of the conclusions. This research project has focused on developing the protocol of an assessment procedure. There was no intention to analyse the application of the procedure as a working management tool, but purely to test the hypothesis that such a procedure is both possible to construct and utilise.

The transition from research tool into an effective management tool will require the committed involvement of both diocesan management and PCC members. Ultimately the successful application of the procedure will be dependent on the custodians of the individual parish churches. From the research completed thus far, however, a series of recommendations to aid its adoption are identified.

10.2.1 Parish church fire safety management: recommendations

- It is considered that the current autonomous approach to parish church property management should be carefully reviewed. An overall fire safety strategy needs to be devised by the diocese for all parish churches in the diocese.
- A peripatetic diocesan estate manager should be employed. This role would entail advising parishes on best practice church maintenance and safety and enforcing diocese policy. The estate manager, as an 'expert', could conduct the fire safety evaluation procedure assessments.
- The quinquennial survey and report should be used as a vehicle for data gathering. All parish churches need up-to-date building plans, records of services and an inventory of valuable content and fabric.

- A church warden in each parish should be instructed by the estate manager so that he/she can be responsible for the day-to-day fire safety management of their parish church. A nominated person should be trained before the church warden finishes his/her term of office so there is continuity in the approach taken.
- All PCC members should undertake periodic training in the basics of fire and security management including item retrieval.
- The diocesan management and selected PCC representative need to be trained in how to utilise and interpret the results from the procedure effectively and how to develop a 'least-cost upgrade' strategy.
- A league table type approach of fire safety in parish churches across dioceses should be encouraged. A national picture of the vulnerability of church fabric and content to fire could then be generated.

10.2.2 The broader application of the procedure

As illustrated in chapter five, fire safety assessment as an exercise follows a generic framework. What makes the creation of 'unique occupancy' schemes individual is the fact that the developed procedure has to accommodate the particular feature of the building and its use, as well as the fire safety objective that is being addressed. This thesis has concentrated on one such application, however, it is now appropriate to consider the potential transferability of the procedure.

- With limited adjustments to the content of the survey worksheets the procedure has the capacity to be applied to any historic building as a structured means of determining the vulnerability of historic property to fire. The uniquely developed vulnerability rating [FVR] sub-framework is generic and may be applied to any building type without adjustment. It is suggested that the process is undertaken in a staged format, starting with trials initially undertaken on historic buildings containing similar characteristics to parish churches such as churches and meeting halls of other denominations to establish the feasibility of the transition. Historic buildings consisting of a complex arrangement of enclosures such as palaces and town properties may well require a different scoring approach.
- It is also considered that the procedure has the flexibility to be used as a life safety evaluation tool. The need for fire safety assessment techniques for 'unique occupancies' has become more acute since the requirement under the Fire Precautions (Workplace) Regulation 1997, amended 1999, for fire risk assessments to be conducted for all workplaces. Parish churches, are how considered to be a

place of work and therefore require an assessment of fire risk to employees to be conducted. There exists at present, considerable confusion amongst employers of all sizes, and from all industries, regarding a suitable assessment approach. The generic framework to the evaluation procedure presents a ready-made assessment procedure specific to the unique features of ecclesiastical estate. As such, it presents itself as a potentially suitable approach for policy adoption by the Church of England.

10.2.3 Evaluation of the methodology

In reviewing the methodology used in this thesis, it is necessary to outline its limitations.

- It must be noted that the procedure developed is an aid to decision making only and should not be used uncritically.
- Using 'expert' knowledge decision making is always open to weakness, but a structured approach has been adopted to minimise problems of actions derived from hunches and personal opinions.
- As the research has been conducted on a regional basis its application in a broader national context cannot be assumed.
- As only pilot tests have been conducted, the repeatability and reproducibility of the procedure have not been extensively tested.

The verification guidelines applied in chapter nine demonstrate that the methodology deployed has produced a procedure which is systematic and clearly discernible, as well as easy to apply, but sophisticated enough to provide a valid assessment of acceptability. The pilot repeatability tests have shown encouraging levels of consistency, illustrating, that with 'expert' knowledge the assessment can be conducted in a technically sound manner.

The primary aim of this research was to develop a prototype fire safety evaluation procedure for parish churches. This has been achieved successfully. The second aim was to examine the effectiveness of the procedure. This has been undertaken at a very elementary level but has provided sufficient evidence to demonstrate the utility of the procedure, both in terms of it being a systematic, repeatable approach and one which enables deficiencies to be identified.

In achieving these aims the thesis has addressed all of the objectives set in the introduction. It is considered that the body of evidence exhibited in this thesis and represented in the conclusion supports the hypothesis, restated at the beginning of this chapter. It is appreciated, however, that only after extensive field testing can true confidence in the methodology be established and the hypothesis conclusively supported or disproved.

10.3 Further work

It now remains to summarise the further work required on the developed prototype evaluation procedure and to suggest areas for subsequent research in the broader context of fire safety assessment techniques and their applications.

10.3.1 Future development work

As a consequence of the pilot testing of the prototype procedure the following developments are required:

- The development of a 'second cut' survey guide and worksheets which start to address the misunderstanding and ambiguities identified with the 'first cut' survey. It is envisaged that four survey drafts will be needed before an effective workable format is achieved.
- A series of field trials are needed to determine the robustness of the procedure in terms of both repeatability and reproducibility.
- Refinements to variable weightings and inter-relationship logic may be undertaken after the results of the field tests are reviewed. This will also include the further evaluation of the desirable fire safety level which needs to be achieved with the aid of diocesan management.
- A more in-depth verification analysis will be necessary when the repeatability and reproducibility of the procedure has been conclusively tested.
- An effective approach to validating the procedure is also required and will be deployed after the field tests have been undertaken.
- A structured approach to determining 'least-cost upgrades' for fire safety systems will be developed but is essentially seen as a major piece of further research.
- The development of a software package to handle the mechanics of the procedure forms the final development stage.

10.3.2 Further research areas

In the future development of 'unique occupancy' fire safety evaluation procedures the following areas are suggested as needing investigation:

- Research into the feasibility of applying the developed protocol to other historic building types.
- Research into knowledge levels for assessors and the concept of knowledge acquisition through an education framework and credit accumulation.
- Development of a generic validation method for 'unique occupancy' assessment schemes.
- Research into the effective integration and interaction between different levels of assessment i.e. from systems involving quantified opinion to computer modelling.
- The development and integration of generic 'least-cost upgrade' option software.

10.4 Closing remarks

And finally, what has been gained by the research project?

This work has taken an existing approach, extended its format and applied it in a different context and to a new building type. In so doing, it represents an original contribution to the development of rationalised systematic fire safety assessment applications.

As an academic exercise, this project has provided a vehicle by which the author has developed, not only in terms of expertise in the field of fire safety evaluation and engineering with specific focus on historic buildings, but also as a building professional, through the rigours of undertaking an original piece of research.

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